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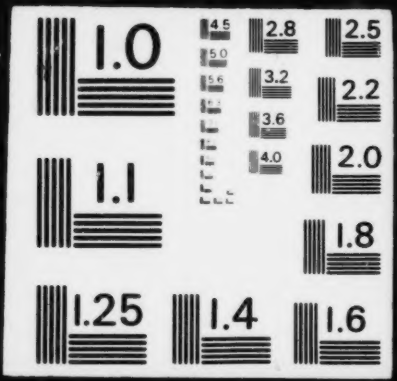
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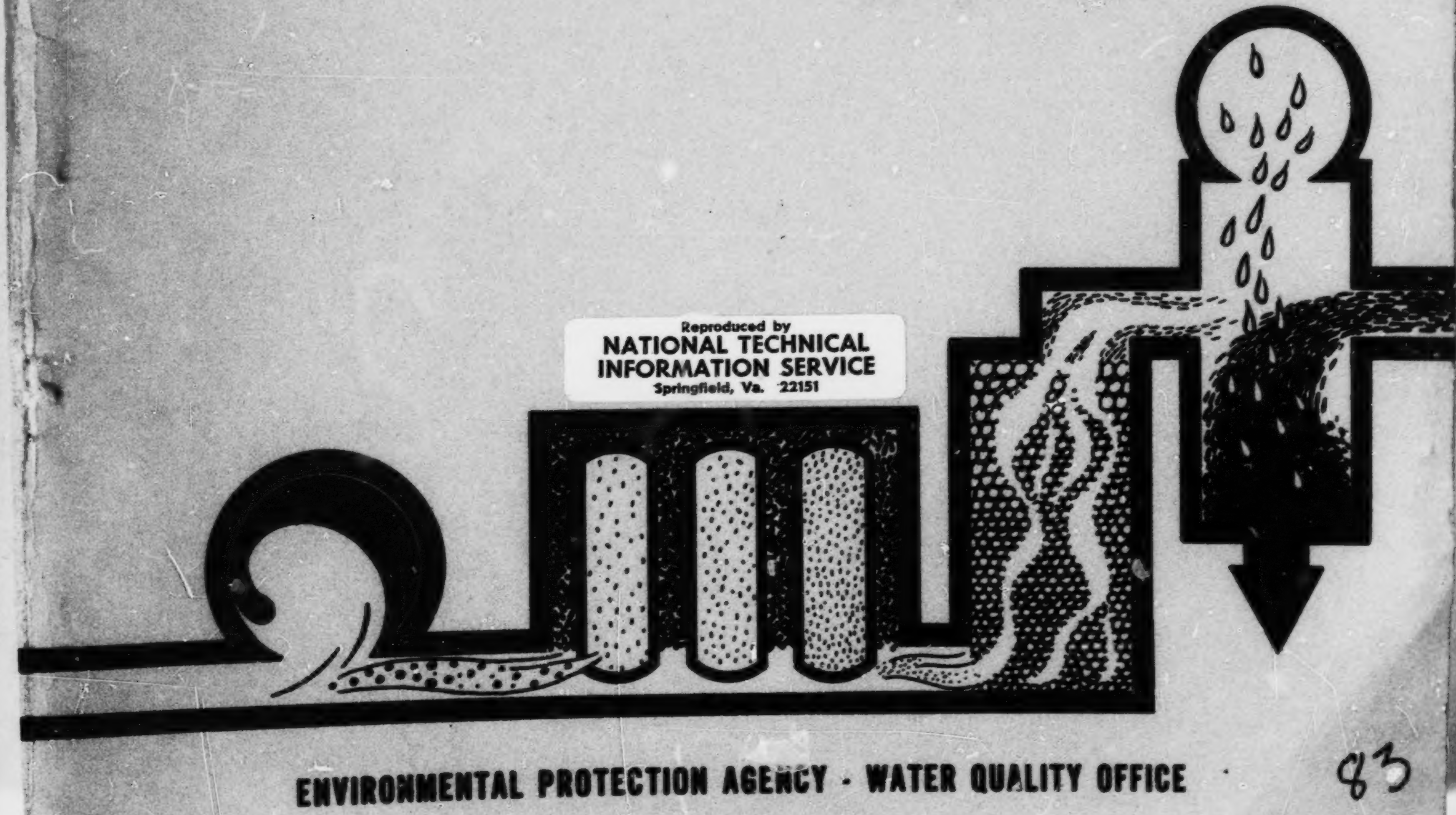
FEASIBILITY OF COMPUTER CONTROL OF WASTEWATER TREATMENT



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16. Abstract

A wastewater treatment study was conducted to: (1) analyze the advantages and limitations associated with the use of computers in the management and control of wastewater treatment facilities; (2) document potential applications and utilization procedures; and (3) recommend further research to achieve full computer implementation for wastewater treatment operations and associated management functions. Current problems and procedures were surveyed, including site visits to plants already automated to some extent. In addition, manufacturers were queried as to the availability of the monitoring and controlling equipment needed. Results indicated that management is indeed interested in automatic controls and computer application, but that both will come about largely on a piecemeal basis. Computer hardware and communication equipment is available and is already being utilized in many instances, but many on-line sensing instruments are not available. (Lowry-Texas)

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FEASIBILITY OF COMPUTER CONTROL OF WASTEWATER TREATMENT

by

American Public Works Association
Chicago, Illinois 60637

for the

ENVIRONMENTAL PROTECTION AGENCY

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ABSTRACT

This report contains the results of an investigation into the use of digital computers for management and control of wastewater treatment facilities. The objectives of the study included the generation of guidelines for implementation of digital computers for these purposes and recommendations for further relevant research.

For the purpose of gathering information, visits were made to plants and the literature was searched. A survey was conducted of current practices and problems in the operation of wastewater treatment plants. Emphasis was placed on the processes of secondary treatment with regard to management and control of unit processes, continuous monitoring needs, the influences of regulatory agencies, and certain local conditions. A set of guidelines and steps for computer control implementation and peripheral applications were evolved.

It was concluded that both off-line computer applications and on-line computer control in wastewater treatment are feasible and should be implemented.

This Report was submitted in fulfillment of Contract 14-12-580 between the Environmental Protection Agency, the American Public Works Association and nineteen cost sharing local governmental agencies.

KEY WORDS: Computers, Wastewater Treatment, Monitoring, Control

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FOREWORD

The completion of this report, Feasibility of Computer Control of Wastewater Treatment, marks the completion of the second phase of APWA Research Foundation Project 66-6 which was designed to investigate the feasibility of computer control of public works processes. The first report, Public Works Computer Applications, was published as APWA Special Report No. 38. The Special Report provides a plan of action for public works officials to computerize information and control systems – or to extend the use of computer systems now in use. The report called attention to the expanding role of the computer for traffic and transportation systems, water supply and distribution, environmental management, and waste collection and disposal. The report offered guidelines on feasibility studies, selecting equipment, preparing staff and space, and beginning operations.

This report is a detailed examination of the use of process computers in wastewater management. The need for this detailed investigation was apparent upon investigation of the uses which have been reported have been primarily for data logging.

In contrast, considerable use of computer process control was found in industrial treatment facilities. Thus, this project was initiated to determine the feasibility of computer process control. The initial report was prepared by the General Electric Re-entry and Environmental Systems Division. General Electric worked closely with the Steering Committee to prepare the final report. Additional input data were provided by the APWA staff. Throughout the study it was pointed out by treatment plant personnel that sensors are not generally available for wastewater treatment plant processes. Sensors that are available have not been designed or constructed for use in this field. Devices which have been installed, generally have been extensively modified.

Manufacturers should work towards the development of requisite sensors suitable for the adverse environment in which they must be used as a design consideration. It is readily apparent that the use of process computers for the control of wastewater treatment plants would materially improve efficiency of plants and plant management and perhaps reduce treatment costs.

Joseph V. Radziul, Chairman
Steering Committee

SECTION 1
SUMMARY AND RECOMMENDATIONS

The summary of this study is reported in the following paragraphs under the headings of *Objectives* and *Conclusions*. Considerations for further action are included in the *Recommendations* part of this section.

OBJECTIVES

The threefold objectives of this wastewater treatment study were as follows:

1. To analyze the advantages and limitations associated with the use of computers in the management and control of wastewater treatment facilities,
2. To document potential applications and utilization procedures, and
3. To recommend further research to achieve full computer implementation for wastewater treatment operations and associated management functions.

The following tasks were completed in support of the above objectives:

1. A survey of wastewater plants was made to determine the critical problems in treatment and whether continuous monitoring and computer control could help solve these problems.
2. Visits were made to wastewater plants utilizing computer applications and automation at Seattle, Washington; Hyperion (Los Angeles), California; Whittier-Narrows, California and Philadelphia, Pennsylvania to assess these applications.
3. Documentation of treatment processes and operational reports were received from the surveyed plants and studied to determine their feasibility for automation.
4. Information on continuous monitoring instrumentation for wastewater treatment was acquired from manufacturers for use in the instrumentation survey.
5. Numerous documents covering automation and treatment were investigated in a literature survey.
6. Meetings and discussions were held with plant management, consultants, government regulatory agencies and the Project Steering Committee.

CONCLUSIONS

Resulting from the above tasks are the following conclusions:

1. While conventional treatment systems do have serious disadvantages and limitations, they will continue to be the most broadly applied for the next 20 years.
2. While no new large scale innovation threatens to replace conventional treatment, modifications to the processes and supplementary processes are being implemented. Examples are chemical coagulation and oxygenation.
3. Personnel pose a real problem in the operation of plants. Difficulties arise in obtaining qualified personnel, in training operators and maintenance men and in reliable follow-through of operational instructions.
4. Interest in computer applications and automatic control is widespread among plant management.
5. A recognition of the advantages of off-line computer uses was unanimous with general appreciation of automated management reporting, maintenance scheduling, inventory control, payroll and accounting.
6. Skepticism was apparent among plant management regarding on-line computer control of plant processes.
7. Computer hardware and communication equipment are available and reliable for use in industrial process control and are suitable for application to wastewater treatment as well.
8. Off-line computer implementation for plant data handling and management information reporting is being successfully practiced; it can serve a wide range of beneficial applications and is fully feasible today.
9. On-line instruments to sense some of the variables considered essential to continuous monitoring and control of wastewater treatment (such as BOD, bacteria and volatile acids) are not on the market.
10. Computer control of the more critical treatment processes, activated sludge and anaerobic digestion is possible in a limited sense

based upon experienced operator control, and will require further study before optimization via computer control is achieved.

RECOMMENDATIONS

The actions indicated from the above conclusions are as follows:

1. Plant management should consider using off-line computer data processing for all areas of plant data handling: reports, maintenance files and scheduling, inventory control, and business areas. Computer availability for off-line applications may exist via a municipal facility, a nearby service bureau, time-sharing or the plant's computer.

2. Studies are recommended to develop the mathematical-logical relationships of the plant physical processes, notably the activated sludge and anaerobic digestion processes. The studies should result in the development of control strategies for supervisory or closed-loop control.

3. Further work must be done in the development of reliable, maintenance-free, on-line sensors. An in-depth survey of users' experience with analytical instrumentation and sensors in wastewater treatment plants should be conducted. The survey would provide guidelines for improvement and innovative approaches to solving the problems of continuous monitoring of wastewater treatment processes.

4. Plant management should give serious consideration to computer control of plant processes, despite the lack of both knowledge and sensors in some areas of wastewater treatment. Today's impetus in plant controls is toward increased application of local closed loops with advanced instrumentation. Some examples are return sludge on the basis of blanket level, aeration rate to maintain a dissolved oxygen level and variable speed pumping for uniform plant flow. These local processes can be integrated to achieve greater operational and economic benefits via computer control of centralized plant monitoring, automatic analyses, timely reporting and improved plant controls. *Only by application of computer control can the wastewater treatment process be optimized as a total integrated system.*

5. Design of new plants or modification of medium size (15 to 50 mgd) existing plants should incorporate automatic controls of the highest degree available. This should yield economies of scale, operation and management and prepare the plant for future conversion to full computer control.

SECTION 2
WASTEWATER TREATMENT PROCESSES AND CONTROL APPLICATIONS

WASTEWATER TREATMENT SYSTEM

The wastewater treatment system comprises wastewater collection, treatment and disposal. All three aspects must be considered in the application of computer monitoring and control. The main emphasis of the study is on the conventional wastewater plant, such as typically shown in Figure 1, through secondary treatment and sludge disposal, and on the role of the computer to upgrade the system. The processes, operational variables and instrumentation for sensing and control are examined from phase to phase with a view toward the feasibility of automatic monitoring and control.

The tertiary and advanced waste treatment (AWT) processes are still relatively new and in the demonstration stage. Although not included in the processes listed in Table 1, some of the techniques are covered briefly in Section 3.

PROCESS CONTROL COMPUTER SYSTEM

The process control computer is the key to automatic monitoring and control of wastewater treatment. This digital computer control system includes:

1. Central processor to perform computations and logic,
2. Core storage to retain both data and instructions for immediate access to central processor,
3. Auxiliary storage, such as disk, drum and tape to retain data and instructions, and
4. Peripheral equipment such as card reader and card punch, input-output keyboard, printer and cathode ray tube for communication with a user.

The process computer has all the capabilities of a purely digital machine. In addition, it has an added set of peripheral components to accommodate the direct monitoring and control of industrial processes, as illustrated in Figure 2. Such computer applications are commonplace in the chemical, petroleum and steel industries among many others.

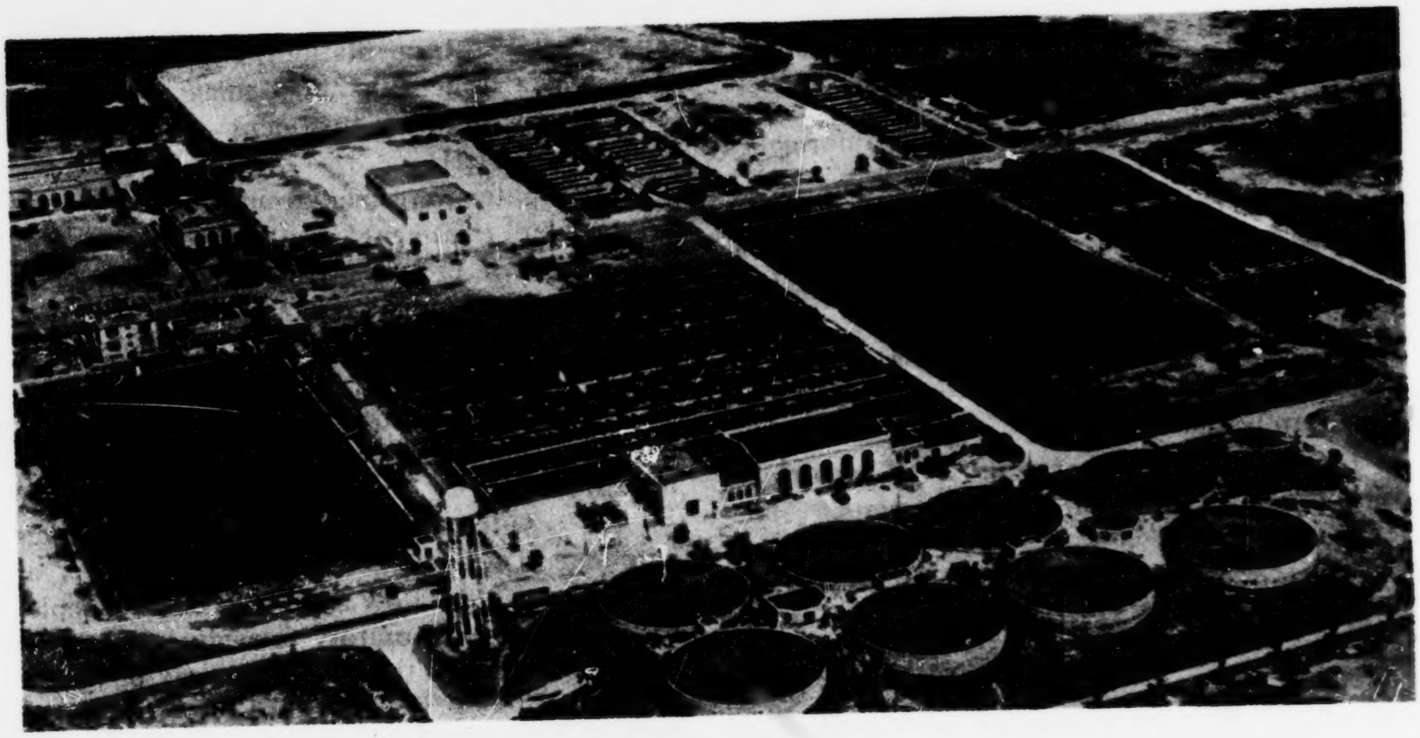

Figure 1. Northeast Water Pollution Control Plant, Philadelphia, Pa. (This plant uses activated sludge and anaerobic digestion.)

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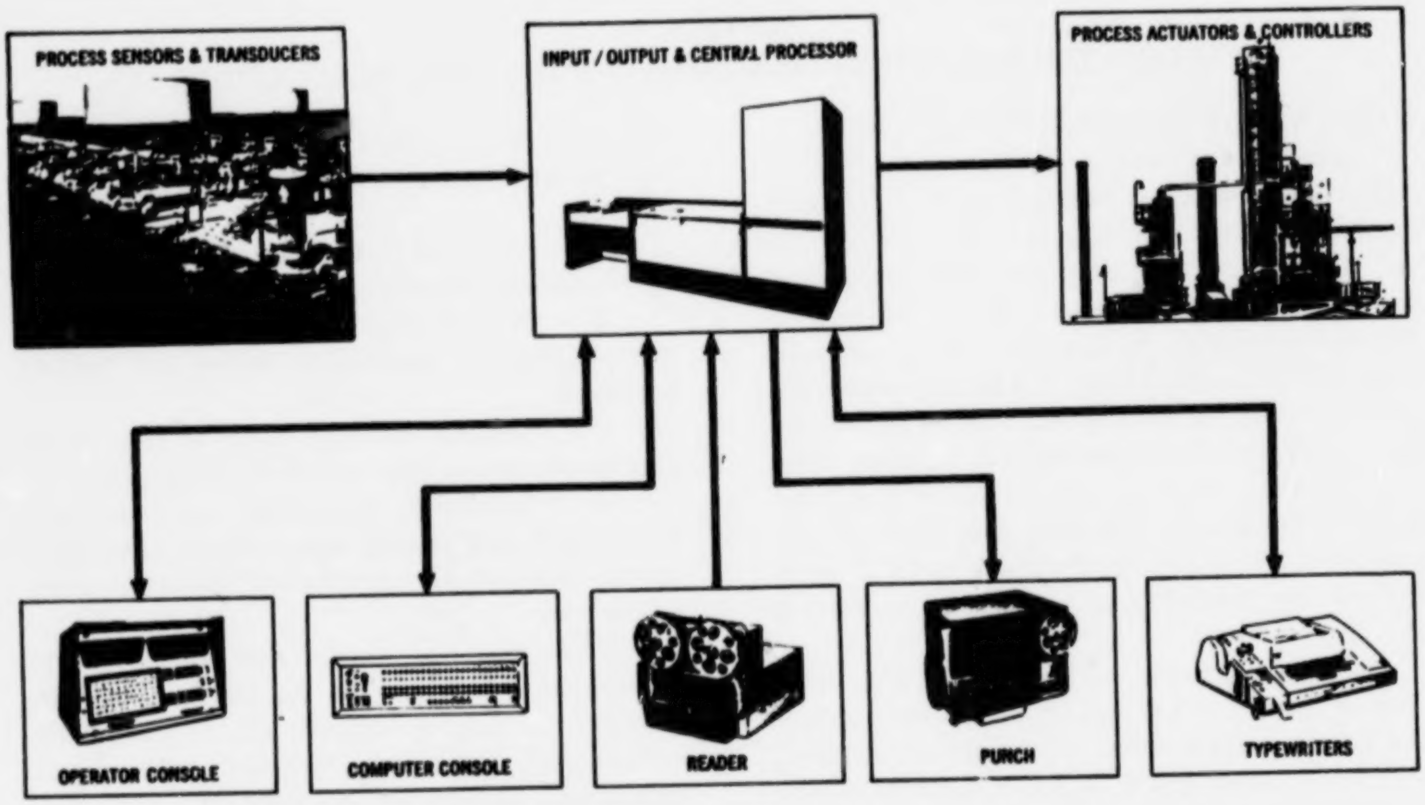
PROCESS SENSORS & TRANSDUCERS
INPUT / OUTPUT & CENTRAL PROCESSOR
PROCESS ACTUATORS & CONTROLLERS
OPERATOR CONSOLE
COMPUTER CONSOLE
READER
PUNCH
TYPEWRITERS

Figure 2. Process Computer, Peripheral Equipment and Industrial Tie-ins

The following is a summary of computer capabilities that suggest a more efficient operation than by manual control. The computer can:

1. Monitor operations and provide accurate, useful information – periodically or on demand,
2. Generate alarms for off-normal conditions,
3. Perform conventional controller functions with greater ease and flexibility,
4. Duplicate consistently the best-known control strategies on a continuous basis,
5. Make programmed decisions on more variables and data than a human – more rapidly, more usefully, and
6. Maintain operating levels among diverse processes within limiting constraints.

COMMON TREATMENT PROCESSES, VARIABLES AND INSTRUMENTATION

Identified in Table 1 are the physical processes prevalent in a large number of treatment plants. Automation of most existing wastewater treatment plants requires an examination of these phases of treatment. Briefly delineated in Table 1 are each function, the role of management, and effectiveness measures for operation. Consideration is also accorded to the existing status of pertinent analytical instrumentation. In Figure 3 is depicted a schematic flow diagram of the common wastewater treatment processes that appear in Table 1.

Computer implementation for control in a wastewater treatment plant necessitates the availability of process monitoring signals on a continuous or sampled data basis. There are two types of instrumentation for acquiring process information:

1. In-stream probe or sensor which generates an analog signal of the variable measured, and
2. Automated analytical procedure (or automated wet chemistry) which samples a quantity from the flow and subjects the sample to an automatic laboratory procedure, requiring reagents. Although the procedure may be rapid, a certain amount of time must elapse before a variable is measured.

Certain wastewater characteristics must be measured to achieve efficient treatment.

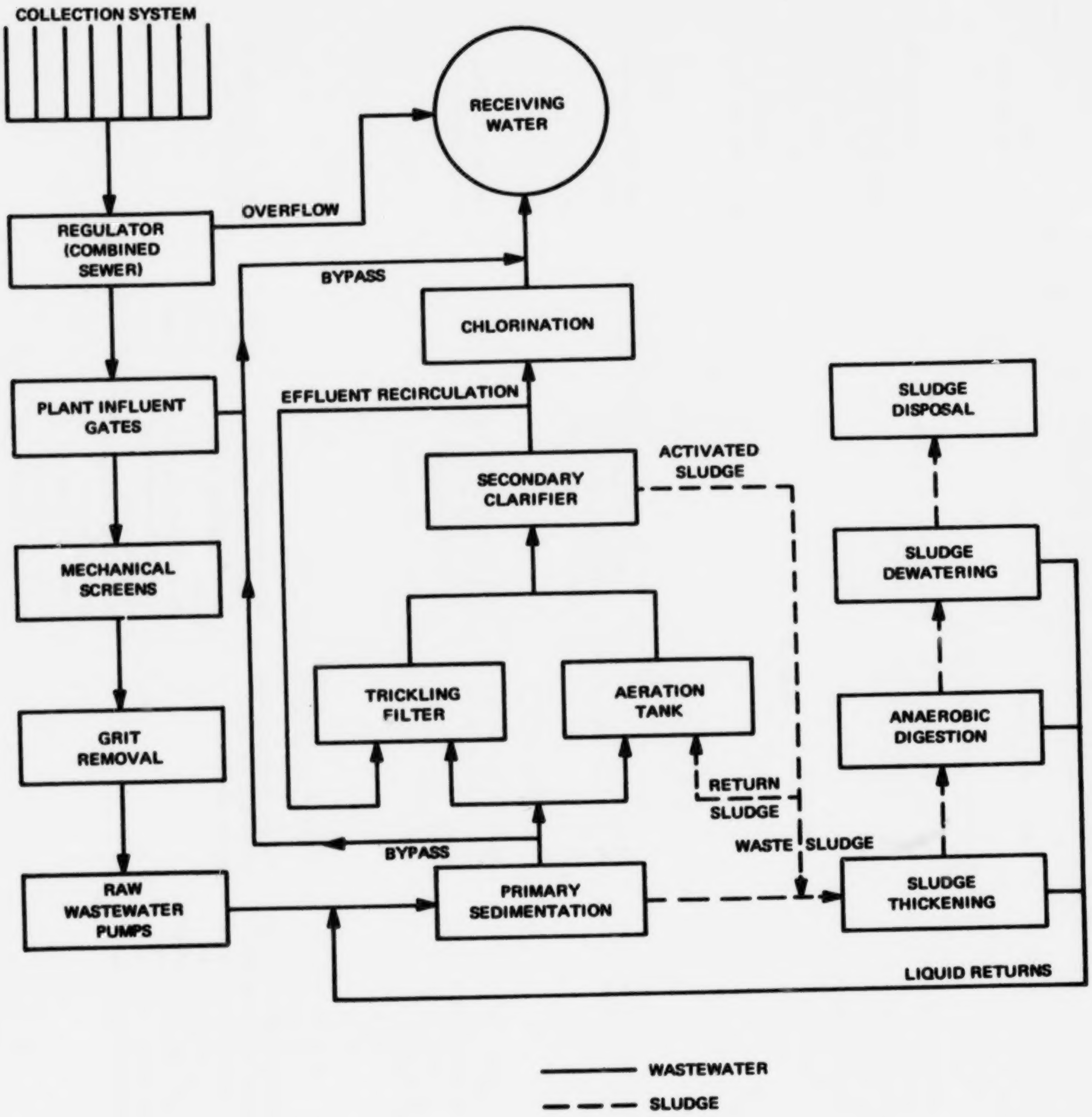
COLLECTION SYSTEM
RECEIVING WATER
OVERFLOW
REGULATOR (COMBINED SEWER)
BYPASS
CHLORINATION
PLANT INFLUENT GATES
EFFLUENT RECIRCULATION
SLUDGE DISPOSAL
ACTIVATED SLUDGE
SECONDARY CLARIFIER
MECHANICAL SCREENS
SLUDGE DEWATERING
TRICKLING FILTER
AERATION TANK
GRIT REMOVAL
ANAEROBIC DIGESTION
RETURN SLUDGE
BYPASS
WASTE SLUDGE
RAW WASTEWATER PUMPS
PRIMARY SEDIMENTATION
SLUDGE THICKENING
LIQUID RETURNS
WASTEWATER
SLUDGE

Figure 3. Common Processes in Secondary Wastewater Treatment

TABLE 1. COMMON WASTEWATER TREATMENT PROCESSES (1 of 6)

Function	Operational management	Effectiveness measures	Monitored variables and use	Available on-line instruments	On-line instrument needs
		Regulator monitoring and control			
Divert excess wet weather flow to receiving waters (in combined sewer systems or systems subjected to excessive infiltration and inflow).	Prevent dry weather overflow. Investigate pollution overflows. Repair malfunctions.	No dry weather overflows. Reduced stream pollution. Reduced surveillance costs.	Depth to detect outfall sewer overflows. Flow to outfall sewer (in dry weather).	Depth	Flow measurement improvement, since Venturi meters and Parshall flumes are difficult to install and expensive. Given sewer cross-section, slope and roughness, the depth measurement could yield a more accurate, computed flow (via computer).
		Plant influent gates			
Regulate raw sewage flow into plant. Allow plant maintenance.	Regulate influent flow to help maintain steady state flow through treatment processes.	Prevention of plant influent surges. Preservation of steady plant flow.	Depth to prevent flood levels in adjacent residential areas. Influent flow to approach steady state design range.	Depth Flow	Adequate (see section 13, Instrument survey).
		Mechanical screens			
Capture and prevent coarse material from entering plant, thereby protecting piping and equipment. Screened material shredded and returned to wastewater or trucked away for disposal.	Optimize screen-cleaning activity. Too little causes excessive back-up; too much leads to high maintenance costs and operational costs.	Minimized influent back-up. Reduced screen cleaning costs. Minimal coarse solids to plant.	Liquid level to detect high head-loss across screen and to initiate cleaning cycle.	Depth Flow	Adequate (see section 13, Instrument survey).
		Raw wastewater pumping			
Raise the level of influent wastewater for continuation through plant.	Maintain steady-state design range flows through plant. Wet well level maintained above minimum level for suction, and below maximum level to prevent flooding. Best control of steady-state design flow through plant.	Control pumping for maximum efficiency and life. Steady plant flow.	Depth of wet well kept within normal limits. Flow to approach steady-state. Electrical power for operation and determination of pump efficiency. Bearing temperature to protect pump. Elapsed time meter to monitor pump life and maintenance requirements.	Depth Flow Power Current Voltage Bearing temperature	Adequate (see section 13, Instrument survey).

TABLE 1. COMMON WASTEWATER TREATMENT PROCESSES (2 of 6)

Function	Operational management	Effectiveness measures	Monitored variables and use	Available on-line instruments	On-line instrument needs
		Grit channel			
To remove abrasive, chiefly inorganic materials, thereby minimizing pump wear, preventing clogging, and simplifying sludge handling and disposal. Removed grit is disposed of by incinerator, burial, dump, or landfill.	Maintain optimal, steady channel velocity to settle high density grit and to pass low density organics. Analyze grit for organic matter to determine grit channel efficiency. Maintain mechanical grit removal equipment.	Minimal appearance of grit in primary settling and subsequent plant equipment, especially in digesters. Minimal organic settling in grit channel.	Channel flow and depth to determine velocity. Grit channel entry as monitoring point for wastewater characteristics (pH, temperature, BOD, COD, DO, TOC, SS, percent volatile matter, phosphates, nitrogen, ORP, toxic metals, and toxic compounds).	Depth Flow pH Temperature COD TOC Phosphates Nitrogens ORP Chromium Copper DO	BOD Phenol Toxic material detector. On-line instrumentation for phosphates and nitrogens, COD and TOC comprises automated analytical procedures (automated wet chemistry). Detection by probe or sensor in the stream flow would be more direct and would yield a real-time measurement. Although a suspended solids on-line instrument is available for the high ranges, none exists that is suitable for less than 500 mg/1, the level of suspended solids for influent wastewater.
		Primary sedimentation			
Remove settlable and floatable solids (and associated BOD).	Ascertain removal of sludge, scum, grease and oil. Minimize downtime of skimming, sludge collecting, and pumping equipment. Maintain proper sludge density for pumping. Determine pollutant removal efficiencies.	Maximum removal of suspended solids in the primary effluent and floatable material. Removals include scum, grease and oil.	Influent and effluent measurements of BOD (or COD or TOC), SS, percent volatile matter to evaluate efficiency of removals. pH and DO in effluent are important to further treatment. Flow over weir controlled and steady to promote sedimentation. Sludge density to control pumping for sludge removal.	COD TOC pH DO Sludge density Flow	BOD to measure removal efficiency. SS to measure removal efficiency. No on-line device has yet proved reliable for primary tank use to measure suspended solids or BOD.

TABLE 1. COMMON WASTEWATER TREATMENT PROCESSES (3 of 6)

Function	Operational management	Effectiveness measures	Monitored variables and use	Available on-line instruments	On-line instrument needs
		Activated sludge (aeration tank)			
Remove BOD and SS by means of biological activity and subsequent settling.	Maintain healthy, active organisms through the balance of influent, effluent, and sludge-return flows. Maintain proper loading rates, satisfactory DO level and good mixing throughout tank. Provide sufficient sampling of variables. Control applied air to maintain aerobic conditions.	Maximized BOD removals and sludge density index. Minimized need for applied air with resultant power savings.	BOD (influent and effluent) to determine removal efficiencies. DO to maintain optimum level in aeration tank for applied air flow. Mixed liquor suspended solids (MLSS) to determine return sludge needs. ORP to indicate the state of oxidation and oxygen utilization. Flow to approach steady-state design range. Return sludge flow to verify required rate. pH as alarm indicator if too far from normal. Temperature for record purposes and correlation studies.	DO MLSS ORP Flow pH Temperature	BOD to optimize return sludge mix.
		Secondary clarification			
Remove solids settling in effluent from secondary treatment units (aeration tanks or trickling filters). Provide activated sludge return to the aeration tank.	Maintain timely removal of properly concentrated settled solids for fresh return activated sludge. Maintain proper level of sludge blanket. Maintain design value of surface application rate.	High removals in effluent of BOD, COD, SS.	Rate of liquid overflow from clarifier to indicate effluent flow. Sludge blanket level in tank to determine start of sludge removal. ORP to indicate condition of sludge. BOD (or COD or TOC) and SS in effluent to indicate removal efficiency. Nitrogens and phosphates to indicate removals of respective nutrients. Temperature for record purposes and correlation studies. DO in effluent to indicate effect on receiving waters. pH as alarm indicator when outside normal range.	pH DO SS Sludge blanket[1] Flow ORP COD TOC[2] Nitrogens Phosphates	BOD No on-line instrumentation is available to directly indicate biological characteristics, such as the status of the bacterial culture in the return sludge.

[1] *Activated Sludge Process Automated*. Water and Sewage Works. May 1970.

[2] Stack, V.T. *Continuous Monitoring Devices – Treatment Plants*. Proceedings Ninth Engineering Conference, Instrumentation, Control and Automation For Water Supply and Wastewater Treatment Systems. University of Illinois, College of Engineering. 1967.

TABLE 1. COMMON WASTEWATER TREATMENT PROCESSES (4 of 6)

Function	Operational management	Effectiveness measures	Monitored variables and use	Available on-line instruments	On-line instrument needs
		Trickling filter			
Remove BOD and SS by means of biological activity in stone or plastic media followed by settling.	Maintain well distributed, unclogged flow, proper loading rates, effluent recycling, and adequate air circulation. Check influent and effluent for removal efficiencies. Prevent toxic or high pH materials from entering.	Steady, continuous flow. High percent BOD and SS removals.	Flow of influent and recycling to retain steady-state design range. BOD to determine removal efficiency. pH as alarm indicator when outside normal range. Temperature for record purposes.	Flow pH Temperature	BOD
		Chlorination (disinfection of effluent)			
Destroy bacteria prior to discharge of effluent into receiving waters.	Maintain satisfactory operational chlorination equipment. Observe safety regulations. Maintain satisfactory chlorine residual.	Overall bacterial kill or bacterial concentration with minimum chlorine application.	Flow to pace chlorine application. Chlorine residual to determine dosage. BOD (or COD or TOC), SS, turbidity to determine removal efficiencies and load to receiving waters. Nitrogens and phosphates to indicate nutrient load to receiving waters. Bacterial content to determine effectiveness of disinfection and load to receiving waters.	Flow Turbidity COD TOC Chlorine residual Nitrogens Phosphates	BOD SS below 500 mg/1 Bacteria sensor Chlorine demand would generate direct determination of required dosage.
		Sludge thickening			
Concentrate a dilute sludge, maintaining a pumpable viscosity.	Control rate of feed. Maintain satisfactory pumping operations. Check sludge blanket density. Monitor flow rates. Extract samples for testing. Control flow of dilution water (when required).	Maximized increase of total solids.	Total solids of influent vs underflow to evaluate thickening efficiency. Percent of volatile matter in influent and underflow to indicate organic loading. Flow and SS content of dilution water to balance influent, effluent measurements. Flow rate of influent, underflow, and overflow to measure loading. BOD (or COD or TOC) and SS of overflow to indicate loading of return to primary sedimentation tank.	Flow SS (high) COD TOC Sludge-density	BOD SS (below 500 mg/1) Total solids Percent volatile matter

TABLE 1. COMMON WASTEWATER TREATMENT PROCESSES (5 of 6)

Function	Operational management	Effectiveness measures	Monitored variables and use	Available on-line instruments	On-line instrument needs
		Sludge digestion (anaerobic)			
Decompose organic matter in a controlled environment devoid of free oxygen. Good digestion yields: 1) An innocuous sludge that de-waters with mechanical filtration. 2) A gas, approximately 65 percent methane, useable for general heating purposes, to heat sludge, or in engines to generate power. Excess is burned. 3) A supernatant liquid of low solids concentration.	Maintain: 1) Safety code 2) Temperature control 3) Continuous feed rate. 4) High solids in feed 5) Complete digester mixing 6) Monitoring of volatile solids loadings 7) Monitoring of digester detention time 8) Minimal pH variation 9) Alkalinity to assure proper buffering capacity 10) Monitoring of volatile acids as digestion indicator 11) Lime feed for pH adjustment 12) Gas burner	Rate and composition of gas formation are reliable indicators of the speed and success of digestion. Volatile solids reduction indicates effective digestion.	1) Raw sludge feed: Total solids (above minimum percent volatile matter) to indicate organic load. pH for preferred range is 6.8 to 7.4. 2) Digester contents: pH for optimal operation range. ORP to indicate oxidation activity. Alkalinity for buffering. Volatile acids to prevent high concentrations. Temperature for optimal value. Total solids to indicate loading. Percent volatile matter to indicate digestible solids. Level indication to keep below maximum, especially with floating covers. 3) Gas produced: Percent CO_2 indicates digester activity. Rising percent CO_2 indicates process unbalance. High methane percent indicates good digester activity. Volume indicates total gas production. 4) Digested sludge: pH of 6.8 to 7.4 is preferred range for digestion. Total solids to indicate good digestion. Alkalinity to check proper buffering. Temperature for optimal digester range. Flow to indicate withdrawal rate.	pH ORP Alkalinity Temperature Level Carbon dioxide Methane Flow	Total solids Percent volatile matter Volatile acids

TABLE 1. COMMON WASTEWATER TREATMENT PROCESSES (6 of 6)

Function	Operational management	Effectiveness measures	Monitored variables and use	Available on-line instruments	On-line instrument needs
		Sludge dewatering (vacuum filtration)			
Reduce the moisture content of sludge to a cake form suitable for disposal by incineration or landfill. Continuous process coats liquid sludge on a porous medium drum through which liquid is drawn by vacuum, leaving the solid to form a cake which is removed. The drum is coated by sludge while rotating partially submerged in a vat. During rotation the coating is vacuum dried, then removed just before that portion submerges again in the sludge.	Maintain: 1) Equipment 2) Proper sludge condition 3) Operating vacuum 4) Drum submergence, speed, and feed rate. 5) Maximum solids concentration in feed. 6) Functioning filter (change if necessary). 7) Sampling for performance evaluation.	Minimal moisture content of removed filter cake. Maximum rate of dry solids cake produced (lbs/sq ft/hr).	1) Sludge feed: Total solids above minimum value. Percent volatile matter indicates organic load. Flow to determine feed rate. Chemical demand to indicate conditioning needs. 2) Cake: Total solids should be of high concentration. Percent volatile solids to indicate organic content. Total weight for total cake production rate. 3) Filtrate: Total solids should be of low concentration. Percent volatile matter to indicate organic content. Flow to indicate rate of liquid separation.	Flow Weight	Total solids Percent volatile matter
		Sludge disposal (at sea)			
Dispose of sludge at sea by barge or pipeline. Digested sludge is preferred because it should be innocuous, of low volatile content, less likely to create nusiance conditions, and more conducive to mixing and dispersion.	Maximize solids concentration in a pumpable sludge. Prevent nusiances from odors, floating material, bottom deposits, and toxic matter. Locate discharge point to prevent beach pollution. Control transport in pipelines to utilize tides for carrying solids away.	Minimal local beach pollution and nusiance at discharge point.	Flow (pipeline) to record disposal rate. Bacterial sampling (pipeline) to monitor area surrounding outfall. Solids content for concentration efficiency. Volume loading (barge) for records. Solids loading (barge) for concentration efficiency.	Flow Density (solids)	Bacteria detection

Measurements are taken at a plant influent point, at certain locations in the treatment processes and at the plant effluent. Those recommended for monitoring at the entrance to the grit channel (as a plant influent point) are shown in Table 1. They include pH, temperature, biochemical oxygen demand (BOD) or chemical oxygen demand (COD) or total organic carbon (TOC), suspended solids (SS), dissolved oxygen (DO), percent volatile matter, phosphates, nitrogen, oxidation-reduction potential (ORP) and toxic metals and compounds. While not necessarily involved in direct control of the grit channel, these measurements indicate the chemical, physical and biological nature of the flow entering the plant. Plant efficiency is determined by the removals of pollutants, such as BOD, SS, phosphates, nitrogen and the toxic matter. Some items such as pH, temperature, and ORP must be within specified normal ranges to allow satisfactory treatment in other plant operations (sedimentation, digestion and the activated sludge process). The variables are discussed in the following paragraphs.

pH

pH indicates the acid-base condition of sewage flow. Fresh sewage is slightly alkaline; stale sewage is acid. pH is important for anaerobic digestion and can be detected automatically with a probe.

Temperature

Temperature is important to certain treatment processes, especially digestion, and is automatically measured with a sensor.

BOD

BOD indicates the oxygen requirements of the organic and chemical matter. BOD removal is a prime function of treatment. No fully acceptable direct BOD measuring device or methodology exists.

COD and TOC

COD and TOC are frequently suggested as substitutes for BOD. Data correlations are being tested at some plants (Philadelphia, Pa.[3] and Seattle, Washington) with varying degrees of success. The following methods of predicting BOD from TC and COD resulted from studies at the Philadelphia Northeast Water Pollution Control Plant, and any correlation, however, is generally characteristic of the plant and its own data and is not usually applicable to other plants.

Method I		Method II	
Simultaneous equations		Linear Regression	
$BOD = 0.82\,COD - 0.98\,TC$		$BOD = 43 + 0.66\,COD - 0.88\,TC$	
Deviation breakdown		Deviation breakdown	
Deviation of estimate from actual (percent)	Percent of time	Deviation of estimate from actual (percent)	Percent of time
0 - 10	50	0 - 10	33
0 - 20	67	0 - 20	92
0 - 30	83	0 - 30	100

COD

COD measures the total oxygen consuming capacity of the wastewater and can indicate the chemical loading on a plant. While COD can be measured quickly by automated wet chemistry[4], there is no continuous monitoring sensor.

TOC

TOC yields an indication of the organic carbon in the wastewater. Through an automated analytical procedure, TOC has demonstrated its applicability in wastewater monitoring[2]. A TOC determination specifically represents oxidation of only carbonaceous materials. While inorganic carbon may cause interference, it is removed by acid treatment of the sample or by a separate determination and subtraction of the inorganic carbon from the total sample reading (TC).

SS

SS solids floating or in suspension, determined according to "Standard Methods", indicate the suspended solids concentration in

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[1] Guarino, C.F. and G.W. Carpentar. *Philadelphia's Plans Toward Instrumentation and Automation of the Wastewater Treatment Process*. 5th International Water Pollution Research Conference. San Francisco, California. July 29, 1970.

[4] Milbury, W.F., V. Stack, N.S. Zaleiko, F.L. Doll. *A Comprehensive Instrumentation System for Simultaneous Monitoring for Multiple Chemical Parameters in a Municipal Activated Sludge Plant*. Preprints 16th Annual Analysis Instrumentation Symposium, ISA. Pittsburgh, Pa. May 25-27, 1970.

the wastewater. A continuous monitoring sensor is on the market (Keene) for the 500 to 5000 mg/l range. Higher ranges can be measured via dilution, but no continuous monitoring instrument is available for direct measurement of suspended solids concentrations of less than 500 mg/l.

DO

DO indicates the oxygen dissolved in the liquid and is essential for bacterial activity. DO is measurable by on-line probe.

Percent Volatile Matter

This is a measure of the organic content in suspended solids in a sampling of sewage. The volatile content is determined by ignition of the suspended solids with a weight loss due to burning of the volatile matter. The inorganic solids remain.

Phosphates

These constitute a nutrient in wastewater. Orthophosphates and total phosphorous can be detected by automated wet chemistry[2]

Nitrogen

Nitrogen indicates the nitrogenous nutrient presence in the wastewater. Automated wet chemistry systems can be used for total Kjekdahl nitrogen, ammonia nitrogen, nitrites and nitrates[2]. The relative quantities of ammonia nitrogen, nitrite and nitrate compounds indicate the degree to which the nitrogen compounds are oxidized (nitrification).

ORP

ORP is the potential required to transfer electrons from the oxidant to the reductant and presents a qualitative measure of the state of oxidation in the treatment processes. Sensors permit continuous monitoring.

Toxic Compounds and Metals

These may be present in sewage, especially industrial wastes. These include phenols and aldehydes as well as hexavalent chromium, copper, cadmium, zinc and nickel. Above certain thresholds, they are toxic to bacteria, especially in the digestion process and can cause a significant reduction in treatment efficiency.

CONTINUOUS MONITORING AND CONTROL

For years analyses in wastewater treatment have depended upon elaborate, time-consuming chemical procedures which yield results too late to exert direct control. While many tests continue to be made on samples in the laboratory, notably BOC, the tests for solids content, bacterial analyses and others are being replaced with the on-line sensors or automated analytical procedures. These new continuous monitoring devices yield rapid intelligence of plant operations and enable the application of timely, corrective measures as off-normal trends appear. The applications of the measured variables in control loops are described chiefly to introduce some broad approaches to the logic and computations suitable for process computer control. Monitoring and control of the common wastewater treatment processes are illustrated in Figure 4.

While many loops can be currently closed via local analog controls, the central computer can simplify the local equipment, accommodate all plant closed loop controls and generate integrated logging and reporting. The general control sequence can be divided into the elements of 1) *Monitoring,* 2) *Data gathering,* 3) *Status determination,* 4) *Data processing,* 5) *Decision making,* 6) *Control execution,* 7) *Verification,* and 8) *Evaluation.*

ENVIRONMENTAL FACTORS

The measurement and recording of rainfall and other meteorological data can add to the total information delivered to the central computer. Such information can be used to relate environmental factors to the treatment plant influent. A specific case is the prediction of flow patterns in the collection system to control routing and storage of such flows in order to prevent hydraulic overloading of a collection system or the treatment plant.

REGULATOR MONITORING AND CONTROL

Centralized monitoring and control of regulators can result in significant reduction of

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[2] *Ibid.*

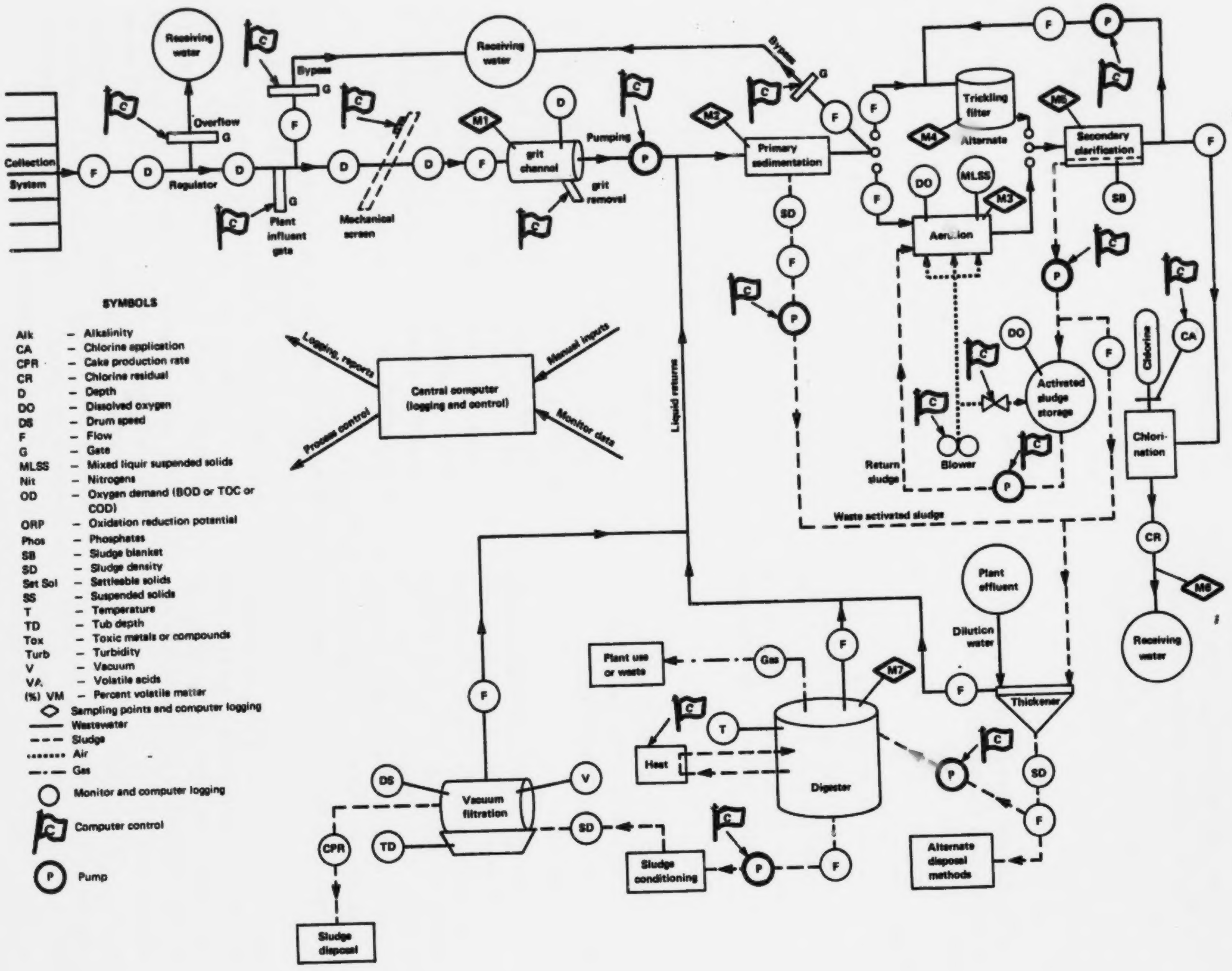
Collection System
Receiving water
Overflow
Regulator
G
Bypass
Plant influent gate
Mechanical screen
grit channel
grit removal
Pumping
Receiving water
Bypass
Primary sedimentation
Trickling filter
Alternate
Aeration
Secondary clarification
Liquid returns
Return sludge
Blower
Activated sludge storage
Waste activated sludge
Chlorine
Chlori- nation
Receiving water
Plant effluent
Dilution water
Thickener
Alternate disposal methods
Digester
Gas
Plant use or waste
Heat
Sludge conditioning
Vacuum filtration
Sludge disposal
Central computer (logging and control)
Manual inputs
Monitor data
Logging, reports
Process control
F
D
P
DO
MLSS
SD
SB
CA
CR
T
V
DS
TD
CPR
M1
M2
M3
M4
M5
M6
M7
C
SYMBOLS
Alk – Alkalinity
CA – Chlorine application
CPR – Cake production rate
CR – Chlorine residual
D – Depth
DO – Dissolved oxygen
DS – Drum speed
F – Flow
G – Gate
MLSS – Mixed liquir suspended solids
Nit – Nitrogens
OD – Oxygen demand (BOD or TOC or COD)
ORP – Oxidation reduction potential
Phos – Phosphates
SB – Sludge blanket
SD – Sludge density
Set Sol – Settleable solids
SS – Suspended solids
T – Temperature
TD – Tub depth
Tox – Toxic metals or compounds
Turb – Turbidity
V – Vacuum
VA – Volatile acids
(%) VM – Percent volatile matter
◇ Sampling points and computer logging
—— Wastewater
– – – Sludge
•••••• Air
—·— Gas
○ Monitor and computer logging
Computer control
Ⓟ Pump

Figure 4. Monitoring and Control of Common Wastewater Treatment Processes

Sampling point	SS	OD	Phos	Nit	pH	ORP	T	Set Sol	Do	%VM	Turb	V.A.	Alk	Tox.
	Variable													
Grit channel, M1	X	X	X	X	X	X	X		X	X				X
Primary sedimentation, M2	X	X			X				X	X				
Aeration, M3		X			X	X	X	X	X					
Trickling filter, M4		X			X		X							
Secondary clarification, M5		X	X	X	X	X			X					
Plant effluent, M6	X	X	X	X							X			
Digester, M7					X	X	X			X		X	X	

PLANT EFFICIENCY MONITORING

Besides the variables monitored (see diagram) others may be applied at key points in the plant for determining plant efficiencies, logging, historical records, and correlation studies. They are not all automatic, and not all need be measured.

DIAGRAM NOTATIONS

Aeration:	DO monitored to determine aeration rate. MLSS monitored to determine return sludge flow. M3 monitoring.
Chlorination:	Chlorine residual monitored to determine chlorine application. M6 monitoring.
Clarification:	Flow monitored for optimal settling. Sludge blanket level monitored to determine sludge removal flow. M5 monitoring.
Digester:	Temperature determines sludge circulation for heating. Gas analysis and other variables determine sludge loading as well as liquor and sludge withdrawals. M7 monitoring.
Grit channel:	Flow and depth monitored to achieve optimal grit settling. Periodic (time- controlled) grit removal. M1 monitoring.
Mechanical screens:	Cleaner mechanism actuated by differential level across screen.
Plant influent gate:	Gate position determined by flow and sewer backup depth.
Primary sedimentation:	Compute total flow for optimal settling. Sludge density dictates sludge pumpage rate. M2 monitoring.
Pumping:	Approach steady state plant flow.
Regulator:	Overflow determined by flow and depth of collection system.
Thickener:	Sludge density determines sludge pumping rate. Liquid overflow return monitored.
Trickling filter:	Flow and wastewater variables monitored to determine recirculation rate. M4 monitoring.
Vacuum filtration:	Operation monitored by tub level, drum speed, vacuum, incoming sludge density and rate of cake production.

NOT REPRODUCIBLE

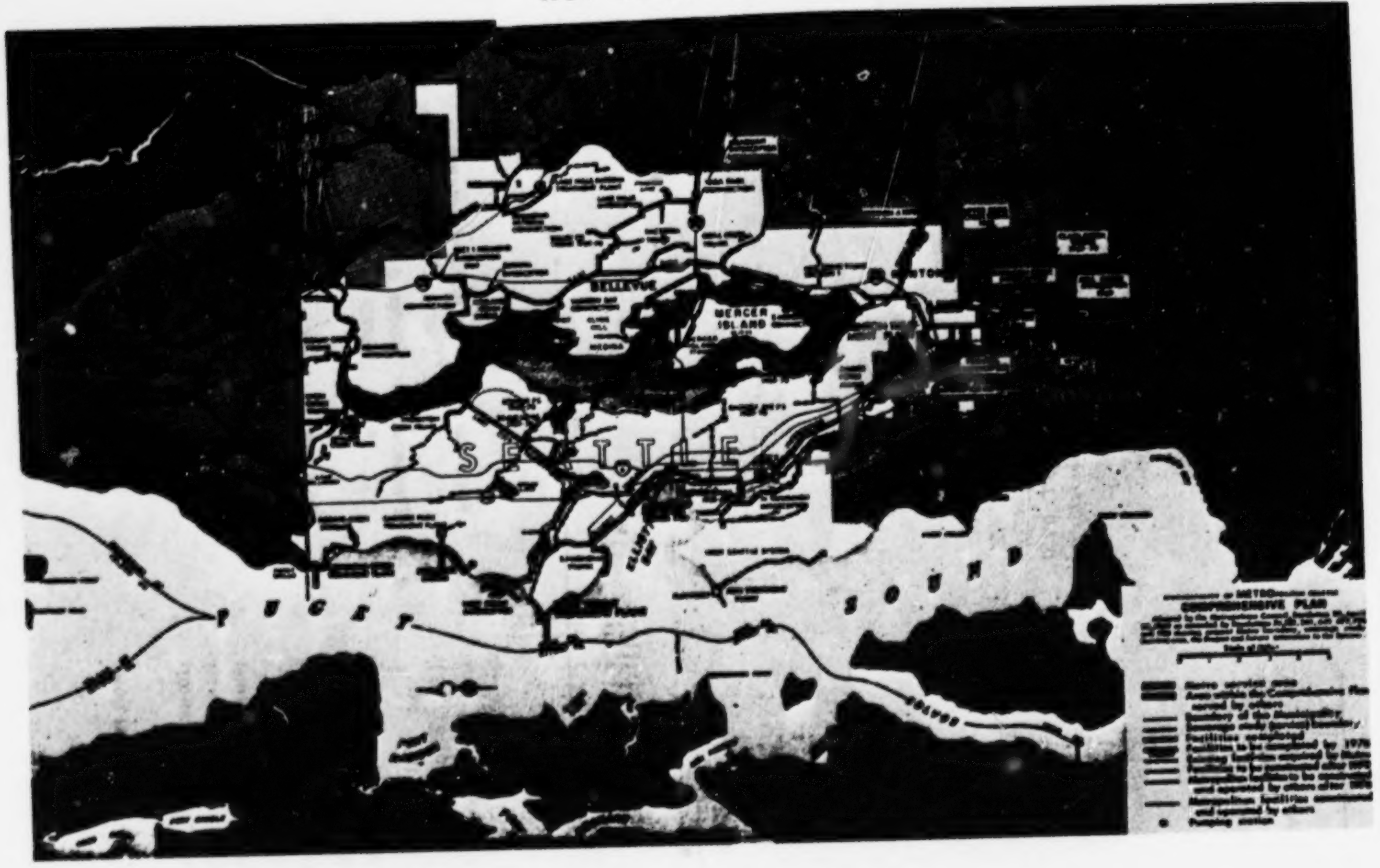

Figure 5. Map of Metro Seattle Wastewater Collection System

combined sewer overflow to receiving waters. To achieve the objective of using available storage within the existing combined sewers for regulating stormwater flows, the Municipality of Metropolitan Seattle, as indicated by the map in Figure 5, is installing a "Computer Augmented Treatment and Disposal System (CATAD)". Reduction of both the frequency and magnitude of wastewater overflow is part of Seattle's objective. It is further anticipated that flow to the treatment plant will be kept under control within specified limits. When overflows cannot be avoided, the system will control discharges at selected stations to minimize harmful effects on marine life or public beaches. Monitoring within the system includes:

1. Level of trunk lines, interceptors and, in some cases, tide,
2. Regulator and outfall gate positions,
3. Influent level and pump speeds at pump stations, and
4. As many as 23 separate alarm and control contact status points.

Implementation of the system over the area indicated in Figure 5 is based upon centralized computer control operating in conjunction with automatic local station controls to utilize storage in the trunk sewers. Within the permissible limits for back-up of wastewater, the computer will control[5]:

1. The position of the regulator gate which diverts flow from the trunk sewer into the interceptor sewer,
2. The position of the outfall gate which allows flow to the receiving waters, and
3. The number of operating pumps and the pump speed to build up storage of wastewater in the interceptor and trunk sewers upstream of pumping stations.

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[5] Metropolitan Engineers. ***Municipality of Metropolitan Seattle Sewage Disposal Project Contract No. 68-1 for Computer Augmented Treatment and Disposal System.*** **March 1968.**

Within the collection system aside from the hydraulic variables, such variables as DO, pH, toxic compounds and metals, gaseous hydrogen sulfide and combustible gas detectors can be monitored from various points to provide useful information for operation of the collection system and the treatment plant. the data can provide early warnings of future maintenance problems and hazardous conditions within the collection system. The data may also help in locating sources of undesirable industrial waste dumps or spills.

GATES

Gate control is utilized to prevent flow surges into the plant while simultaneously avoiding nearby residential flooding due to excessive back-up.

Under computer control, internally stored reference flows and depths for the sewer system can be compared with measured flows and depths to determine the desired gate setting and to deliver the adjustment signal as necessary.

On-line monitoring is especially applicable to a multiple influent gate system where two or more gates are regulating raw sewage flow to the plant, and the problem of simultaneous control is more complex. With computer stored intelligence of system capacity, programmed schemes can control emergencies in combined sewer collection systems (such as local storms). The high flow from one part of the system may be permitted to enter the plant while a low flow component is further reduced via gate control, utilizing the permissible back-up in the sewer. Where the situation approaches the allowable system capacity constraints, an alarm can signal off-normal conditions.

MECHANICAL SCREENS

Removal of coarse material from the plant influent causes an accumulation of debris on the upstream side of the screen. This creates a sufficiently large difference in water level across the screen for automatic control to initiate the scaper activity thereby removing the coarse material for disposal. The time interval between checks should not exceed 1/2 hour.

Should the scraper malfunction, an alarm can be triggered on the basis of no scraper activity, excessive influent main depth, excessive head-loss across screens, and excessive flow reduction.

To prevent scraper breakdown, a counter for the number of cleaning operations or an elapsed time meter could signal the optimal period to apply preventive maintenance to the equipment.

GRIT CHANNEL

The effectiveness of grit channel operation is based upon differential sedimentation. The flow velocity through the channel is slow enough to allow the high density grit to settle, while the lower density organic solids remain in the effluent. Flow and depth in the grit channel should be monitored so that the velocity can be kept constant despite wastewater flow variations.

Through use of multiple, parallel channels, continuous monitoring and control can regulate the division of total flow among the channels. The number in use as well as the optimal velocity of the channels can be determined according to total plant influent flow.

Grit removal by mechanical devices such as scrapers, conveyors and screws should be monitored for operation every half hour to prevent possibility of miring under too heavy grit deposits.

RAW WASTEWATER PUMPING

Monitoring of pump operation can accommodate the following functions:

1. Maintaining steady state plant flow,
2. Prevention of flooding condition,
3. Pump cycling and speed changes to accommodate flow changes and to increase pump life,
4. Pump operation at peak efficiency,
5. Prevention of excessive power demand factor,
6. Alarms for off-normal flow and level conditions,
7. Alarms for pump malfunction, and
8. Alarms for bearing temperature.

With the above conditions under continuous monitoring, a computerized mathematical model can be developed from the pump requirements for control of raw wastewater pumping. Control of flow into the plant via variable speed pumping can minimize hydraulic transients. Complex multiple influent channels and pumping requirements are feasible for computer control.

PRIMARY SEDIMENTATION

The requirements of primary settling include a steady, optimal surface application rate and overflow weir rate to promote solids settling, and sludge density monitoring for control of solids removal. Floating debris is removed by a skimming device for discharge into a scum sump and subsequent disposal.

Monitoring of the surface application or overflow weir rate can exert control on the rate of flow to the primary tank to maintain design flow rates.

Sludge removal can be based upon sludge density. Under density monitoring, a thick sludge is preferred for efficiency of removal and for subsequent treatment. The upper limit on sludge density is based upon the pump capability. Control of the mechanical collectors also contributes to sludge density. Time intervals between sludge removal cycles should be adjusted to maintain aerobic conditions throughout the sedimentation tanks.

ACTIVATED SLUDGE (AERATION TANK)

Aeration tank control involves:

1. Flow rate of influent (from primary),
2. Flow rate of return sludge,
3. Flow rate of effluent,
4. Flow of air to maintain dissolved oxygen (DO) levels, and
5. Sampling and measurement of wastewater and mixed liquor characteristics to determine operating levels.

A real time BOD reading *could optimize our mix on a minute-to-minute basis*[6] a quote from one plant operator. Since there is no acceptable continuous BOD monitoring instrument, other properties of wastewater must be used for control of the aeration tank mix.

One alternative is to measure the concentration of mixed liquor suspended solids (MLSS)[7] which can be used to determine the return sludge flow. However, the concentration of solids in the aeration tank liquor is strongly dependent upon the nature of the wastewater[8]. This would require therefore a local adjustment of the MLSS – return sludge relationship based upon the operator's experience.

Aeration may be applied by diffused air generated by blowers or mechanical agitation. Control is expedited via the quantity of diffused air or power to the mechanical aerators. The loop is closed by signals from strategically located DO probes in the tank to maintain an optimal DO level consistent with the needs of bacterial activity and economy (prevention of excessive power usage). Monitoring can be continuous with DO probes, but an outage should not exceed a half hour.

Biological systems are sensitive to step changes[9] in the wastewater characteristics. Sudden temperature changes can increase effluent turbidity of the clarifier, and sudden changes in BOD or pH can cause the sludge blanket to deflocculate. Maintaining constant conditions tends to stabilize the process, however, plant influent characteristics are subject to sudden changes in chemical nature. Continuous monitoring and computer data logging can alert operators to indications of changing characteristics.

Optimal control of aeration tank activity must be integrated with clarifier control, since they are sequential processes with controlled feedback.

The direct use of oxygen for aeration from on-site oxygen generators or sale of the gas is currently being tested and proving economically feasible. The supply of oxygen can be automatically controlled in direct proportion to the BOD of the influent wastewater[10]

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[6] *Crises in the Megalopolis Demand New Electronics.* Electronic Design 1. January 4, 1968.

[7] *Mixed Liquor Suspended Solids Analyzer/Controller,* Bulletin No. 8200. Keene Corporation Water Pollution Control Division, Aurora, Illinois.

[8] Cosens, K.W., *The Operation of Sewage Treatment Plants.* Public Work Publication.

[9] Knowles, C.L., *Improving Biological Processes.* Chemical Engineering/Desk Book Issue. April 27, 1970.

[10] *Oxygen Can Replace Aeration.* The American City. June 1970.

TRICKLING FILTER

Control of trickling filter operation is again a matter of maintaining a steady state influent in both flow and wastewater characteristics with no material in the flow toxic to bacteria. Forced air draft may be added to improve aeration in the filter.

With little to control, good continuous monitoring and logging of the variables which can affect operation such as pH, temperature, influent flow return (where used), flow and toxicity, can help improve operations.

SECONDARY CLARIFICATION

Control in secondary clarification comprises:

1. The maintaining of the proper sludge blanket level,
2. The removal of as concentrated a sludge as possible within the constraint of pumpability,
3. The removal of settled sludge as quickly as possible to prevent septicity, and
4. The setting of the proper fraction of sludge removal for return to the aeration tanks as *seeding*.

Since the purpose of the return sludge is to provide thriving bacteria to meet the aeration tank influent, the wastewater characteristics of that influent are also important. Optimal control of return sludge flow should be based upon flow, temperature, pH and DO, as well as on BOD. Of further importance is the population and health of the bacteria. No sensor exists to identify either the species or condition of the bacteria.

In one article a successful application of sludge removal on the basis of blanket level control is described.[1] A sensing head probe is located at a preset level in the settling tank and detects the sludge blanket level via the gap between an infrared source and a photocell. When the blanket reaches the specified level, the light source is cut off, initiating the sludge draw-off mechanism from the tank. As the sludge blanket drops below the desired level, the sensing head probe halts sludge draw-off. While sensing can be continuous, the interval between checks should not exceed five minutes.

Nevertheless, to accommodate the factors relating to the return sludge flow would require a comprehensive study to determine the nature of the relationships among the variables from which the control model could evolve.

CHLORINATION

The chief function to control is chlorine dosage which can be done automatically as a combination of pacing with flow and adjusting the rate by the chlorine residual measurement. The residual recorders measure the free chlorine remaining in the flow after a specified contact period and yield a dosage verification which is converted to a dosage adjustment for subsequent flow. Close control is important since insufficient feed rate will not fully destroy bacteria, and too much is wasteful. The interval between checks should not exceed five minutes. A chlorine demand instrument would determine the dosage directly.[11]

MONITORING OF RECEIVING WATER

Monitoring of receiving water is certainly a part of the total wastewater treatment system. Besides chlorine residual of the plant effluent, such variables as DO, pH, turbidity and conductivity are monitored in the receiving water. Other variables are cited for measurement in Table 4, Measurements for Wastewater Treatment Processes. Aside from plant effluent area, water quality stations may be located both upstream and downstream of the plant.

In most areas, regulatory agencies collect this information. Hence this topic is further covered under Section 5, "Data Needs of Regulatory Agencies."

SLUDGE THICKENING (GRAVITY)

Sludge thickening by gravity is similar to primary sedimentation where solids are concentrated to form a sludge blanket. The chief control operation is proper removal of the thickened sludge. Through utilization of a nuclear radiation or sonic device, the density of the thickened sludge can be continuously monitored to initiate intervals of removal by pumping.

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[1] Water and Sewage Works. *op. cit.*

[11] Hess, A., and H.F. Hanson. *Water, Water Everywhere, But–*. Control Engineering. May, 1970.

SLUDGE DIGESTION (ANAEROBIC)

Anaerobic digestion is a critical operation easily subject to instability. In the process bacteria groups work simultaneously to consume organic matter. One group breaks down the material to the acid stage, while another continues the conversion to methane and carbon dioxide. In a favorable environment, a balance is maintained among the different groups; the acids are consumed as they are formed, and the pH remains in a suitable range for the methane bacteria.

Instability is a problem because of the generally greater prevalence of acid producing bacteria over methane bacteria. Thus, unless a digester has been sufficiently *seeded* and properly fed, the smaller population of methane bacteria may be unable to keep pace with the acid forming bacteria. As the production of acid lowers the pH, the methane bacteria become seriously inhibited.

The variables involved in digester operation include temperature, pH, alkalinity, carbon dioxide, methane, volatile acids, percent volatile matter, rate of raw solids feed, rate of digested sludge removal and rate of supernatant liquor removal.

Volatile acid determinations provide valuable information concerning the anaerobic degradation of raw organic solids as well as the environmental conditions for methane production.[12] While the value of the volatile acid test is recognized, it is a laboratory procedure.

Gas analysis is another indicator of digester activity and can be performed on-line. The proportion of methane and carbon dioxide remains fairly constant during normal operation. However, at the onset of digestion troubles, the carbon dioxide content of the gas increases. Continuous gas analysis can indicate satisfactory or off-normal operation and is useful to control digester activity (with volatile acid testing to confirm conditions).

Temperature is essential to satisfactory digester activity and should be kept around 95 deg F. Heat application can be controlled by the digester temperature.

pH can indicate the presence of excess volatile acids. Below a pH of 6.5, methane producing activity becomes inhibited. An acid neutralizing agent, such as lime, will raise the alkalinity and bring back more favorable conditions of pH (around 7.2) for methane production. Thus pH or alkalinity monitoring can control lime feed.

The addition of raw solids and sludge removals must not disturb the desired delicate volatile acids – methane balance.

Sludge density or solids content of the feed should also be monitored to assure proper loading to the digester tanks. Pumping a thin sludge may wash out the alkalinity and upset digester balance.

There are many factors involved in monitoring and controlling digester activity, and they can be synthesized into a mathematical model. In its simplest sense, (using continuous monitoring variables) pH can determine lime feed; gas analysis and sludge density can determine raw solids feed and sludge removal.

A mathematical model was developed to study anaerobic digestion, [13] and its problems of failure and start-up. The quantities cited as effective in decreasing start-up time and preventing digester failure were seed sludge, pH and digester loading. To study the problems of digester start-up and failure, which are transients rather than steady state operation, necessitated use of a dynamic (time-varying) model. In this case a steady state model would be ineffective.

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[12] Sawyer, C.N. and P.L. McCarty. *Chemistry for Sanitary Engineers*. McGraw-Hill Book Company. 1967.

[13] Andrews, John F., *Dynamic Model of the Anaerobic Digestion Process*. Proc. Paper 6418. Journal of the Sanitary Engineering Division, ASCE, pp 95-116. Feb., 1969.

SLUDGE DEWATERING (VACUUM FILTRATION)

Although sludge is most frequently dewatered in open or covered drying beds, controls are minimal. The vacuum filtration technique was selected for discussion because it can save labor, is rapid and is suitable for automated control.

In this process a thickened and conditioned sludge coats a filter on a rotating drum through which a vacuum extracts the liquid. Continuous monitoring should include flow, density and chemical conditioning of influent sludge, level of drum submergence, effectiveness of the vacuum, effectiveness of the filter, drum rotation and rate of sludge cake produced. Information brought to the computer can be logged and checked for values outside normal ranges to trigger alarms.

Equipment control is chiefly maintenance of the proper level of drum submergence in the sludge tub to keep up with removal by coating of the rotating drum. Closed loop control operates the sludge flow to the tub to retain the set point level.

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SECTION 3
SOME ASPECTS OF HIGHER ORDER TREATMENT

INTRODUCTION

Continued refinement and higher removals beyond secondary standards are becoming a necessity in the search for quality effluent from wastewater treatment plants. Thus, secondary effluents are being subjected to further processing involving chemical application, settling, filtration and mechanical separation.

Those briefly considered here are described with respect to the process, its removal capability and requirements for monitoring and control. They include microstraining, chemical coagulation and settling, filtration, carbon columns, ammonia stripping, and ion exchange.

The examples of higher order treatment cover *tertiary* for increased removals of BOD and suspended solids and advanced waste treatment (AWT) for special removals such as phosphorus, nitrogen or minerals. Refined removals of suspended solids, organics, inorganics and nutrients are covered.

MICROSTRAINING

Microstraining removes suspended solids and the associated BOD. The microstrainer[14] equipment consists of a rotating drum covered with a very fine stainless steel woven fabric through which wastewater is strained. As the drum revolves, wastewater enters through one end under gravity and strains out through the drum wall, leaving suspended material trapped on the inner surface. Meanwhile above and outside the drum, jets of water strike through the mesh and force the trapped material into a trough just inside the drum to be carried away as waste washings to the primary settling tank.

The microstrainer performs mechanical separation of solids. Therefore any BOD removals are associated with the suspended solids. Results from different operational studies showed varying degrees of removals:

SS: 50-89 percent of influent
BOD: 30-81 percent of influent

Supervision is minimal with an intelligent operator checking equipment once a shift.

Continuous automatic monitoring could detect local electric power, water level, drum rotation, raw water influent flow, strained water effluent flow, washwater flow, and wastewater flow. The information could be logged periodically with allowance for an alarm upon detection of an off-normal value.

Continuous turbidity measurement could monitor the improvement of clarity. Samplings would be required for laboratory tests of BOD and suspended solids. It is also important to continuously monitor head loss across the microstrainer to indicate blockage.

CHEMICAL COAGULATION

The addition of chemical coagulants such as alum and lime to secondary effluent in a rapid mixing basin initiates the chemical coagulation process.[15] This *flash* mixing is followed by gentle agitation by rotating paddles to form large size floc which traps solid particles including organic matter and bacteria. The solids are then settled in a basin and removed by sludge scrapers, while the effluent flows over weirs into collecting troughs. Coagulant aids such as activated silica, clay and polyelectrolytes are also used to enhance floc formation and improve settling.

In a feasibility study at Dayton, Ohio, where chemical coagulation and settling were applied to secondary effluent,[16] the following conclusions were drawn:

1. Overall phosphate removal was 89 percent with alum, 89 percent with lime at pH of 9.5 and up to 97 percent with lime at pH of 11+.
2. At a pH of 11 the chemical treatment phase was capable of reducing the phosphate

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[14] Dixon, R.M. and G.R. Evans. *Experiences with Microstraining on Trickling Filter Effluents in Texas.* 48th Texas Water and Sewage Works Associations Short School. March, 1966.

[15] Marks, R. H. *Wastewater Treatment.* A Special Report, Power. June, 1967.

[16] Tossey, D.F., P.J. Fleming, and R.F. Scott. *Tertiary Treatment by Flocculation and Filtration.* Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers, 7106 SA1. Feb., 1970.

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content from 28 mg/l to 1.5 mg/l, a greater than 94 percent removal.

3. Chemical settling significantly improved effluent quality over plain settling.

4. Overall BOD removal up to 97 percent was achieved.

5. With alum and silica the chemical treatment phase was capable of reducing the BOD content from 26 mg/l to 4 mg/l, an 84 percent removal.

6. Overall suspended solids removals were 89 percent with indications, however, that a portion of the suspended matter may have been chemical coagulant.

7. With alum and silica the chemical treatment phase was capable of reducing the suspended solids content from 127 mg/l to 21 mg/l, an 83 percent removal.

Clarification efficiency can be continuously monitored via turbidity measurements, while BOD and suspended solids tests are performed in the laboratory. Continuous monitoring should include analyses of the wastewater characteristics, such as pH, temperature, and DO.

Choice of coagulant and coagulant aid will depend upon the results of experimentation at the plant. With a choice selected, the dosage must also depend upon experimentation such as the *jar test*.

It is possible to relate coagulant dosages to plant variables suitable for continuous monitoring such as pH, temperature, turbidity and wastewater characteristics of influent and effluent flow. Other variables relating to coagulation are zeta potential and streaming current, which have possibilities for development into continuous, on-line instruments. Where these measurements are feasible, an empirical relationship can be developed suitable for implementation in a process computer to control dosage application.

FILTRATION

Filtration is generally used on the effluent from chemical coagulation and settling. The filter media is usually sand and other media such as anthracite. As the wastewater flows through the filter bed, suspended particles are captured, thereby effecting a reduction in turbidity. However, through continued use of the filter, the trapped particles build up head loss, necessitating removal of the material by filter washing.

In the City of Dayton study[16] referred to under Chemical Coagulation, rapid sand filtration was used to polish the effluent of the wastewater treatment plant. Some of the results of filtration usage were:

1. With no prior chemical treatment, filtration of settled trickling filter effluent produced overall removals of 91 percent suspended solids and 80 percent BOD during poor trickling filter performance. When trickling filter operation improved, the corresponding figures for sand filtration resulted in an overall removal rise for BOD to 95 percent.

2. Following chemical treatment it was also stated, "It was possible to polish effluents to a higher degree than plain settling alone".

3. When preceded by chemical coagulation, the filtration phase of treatment removed 30 percent to 70 percent of the applied phosphate load.

Steady flow and gradual flow changes are essentials for filtration control since transients cause increases in effluent turbidity or breakthrough. Flow and limitations on the rate of change of flow can be monitored and controlled via computer. In open tank filters, continuous monitoring is also important for tank level to prevent flooding, head-loss to initiate backwash and level of water storage (for backwashing). Pumps for feed and backwash should also be monitored.

To measure filter efficiency, turbidity can be monitored automatically, but suspended solids (low levels) and BOD analyses must be performed on samples in the laboratory. All continuously monitored data can be computer stored for logging, off-normal checking to alarm and management reporting.

The initiation of backwash as well as the backwash cycle can be controlled by computer. A simple routine can examine information acquired from the filter, and on the basis of response to a few questions, determine whether

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[16] Tossey, D.F., et. al., *op.cit.*

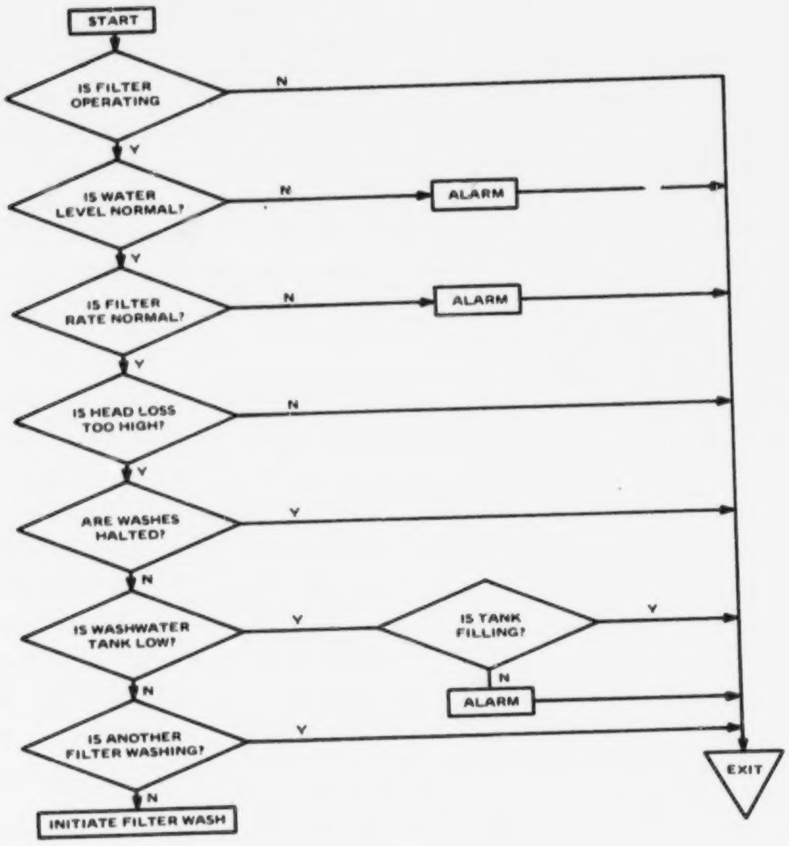
START
IS FILTER OPERATING
N
Y
IS WATER LEVEL NORMAL?
N
ALARM
Y
IS FILTER RATE NORMAL?
N
ALARM
Y
IS HEAD LOSS TOO HIGH?
N
Y
ARE WASHES HALTED?
Y
N
IS WASHWATER TANK LOW?
Y
IS TANK FILLING?
Y
N
ALARM
N
IS ANOTHER FILTER WASHING?
Y
N
INITIATE FILTER WASH
EXIT

Figure 6. Filter Backwash Monitor

to start the cycle. Information is examined on whether the filter is in operation, the head loss is too high, the washwater tank is sufficiently full, and another filter is operating. If the proper responses are received the filter is submitted to the backwash cycle. The monitoring scheme is flow-charted in Figure 6.

ACTIVATED CARBON

Filtering wastewater through granular activated carbon results in adsorption and absorption of biodegradable and non-biodegradable organic matter. Turbidity and color are also significantly reduced. Batch mixing of carbon is commonly used in municipal water treatment to remove tastes and odors. However in wastewater treatment, columns of granular activated carbon are considered more practical to use because separation and regeneration of spent carbon for reuse present less difficulty than the batch process.[17] The carbon is periodically rejuvenated by draining to concentrate the slurry and by high temperature furnace heating to remove the adsorbed organic matter. The cycle of use and reactivation results in a 5 percent loss of granular carbon.[15]

In operations at the South Tahoe Public Utility District "over 80 percent of all organic material found in the secondary effluent was removed by carbon treatment".[18]

At a Pomona pilot treatment plant[19] a carbon adsorption system was operated for over a year with achievement of over 90 percent

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[17] Burleson, N.K., W.W. Eckenfelder, and J.F. Malina. *Tertiary Treatment of Secondary Industrial Effluents by Activated Carbon*, 23rd Industrial Waste Conference, Purdue University. Lafayette, Indiana.

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[15] Marks, R.H., *op. cit.*

[18] Slechta, A.F. and G.L. Culp. *Water Reclamation Studies at the South Tahoe Public Utility District*. Journal Water Pollution Control Federation. May, 1967.

[19] FWPCA U.S. Dept. of Interior. *Summary Report Advanced Waste Treatment*. Publication WP-20-AWTR-19.

suspended solids and 80 percent total COD removals (77 percent dissolved COD removal). At the same time regeneration losses averaged 10 percent.

Some absolute figures on carbon column removals in the Pomona study included:

SS (mg/l): from 10 to less than 1,
COD (mg/l): from 47 to 9.5,
TOC (mg/l): from 13 to 2.5,
Nitrate, as N (mg/l): from 6.7 to 3.7,
Turbidity (JTU): from 10.3 to 1.6.

The sizeable nitrate reduction was attributed to biological activity within the carbon column.

In the Pomona operation continuous carbon column monitoring for efficiency included COD, TOC, ammonia and ultraviolet absorbance (2537 Angstrom). It was found that ultraviolet absorbance correlated well enough with TOC to be considered as a possible control variable for operation.

One of the most important functions of monitoring is to determine when the carbon adsorptive capability is spent. At the South Tahoe installation where COD and TOC are continuously monitored, carbon is withdrawn for reactivation when COD reaches 20 mg/l or TOC reaches 7.5 mg/l.

AMMONIA REMOVAL BY AIR STRIPPING

Ammonia stripping is a technique for removing volatile NH_3. Ammonia may exist in water as volatile NH_3 or ionized ammonium, NH_4^+. When the pH is raised to 10 or above in the wastewater, the predominant form of ammonia is the NH_3. Being volatile it can be driven off as a gas by air-contact. This is accomplished in towers where the liquid flows steadily downward as air is blown across.[19]

Experimentation to seek economically high removals continues with variation in tower size, configuration, internal structure, pH and flow rate of wastewater, flow rate and direction of air, and recycling. Removals of ammonia from 85 to 95 percent were achieved under different conditions. Greater air circulation can boost removal to 98 percent.[18]

Some advantages of nitrogen removal by ammonia stripping include:

1. Gaseous form removal, requiring no extra handling,
2. No requirement for nitrogen conversion to nitrate, and
3. Increase of the pH to a range suitable for ammonia stripping by previous lime coagulation for phosphate and turbidity removal.

Some of the problems which arise with ammonia stripping include: 1) poor efficiency in winter due to freezing of water and high solubility of ammonia, and 2) formation of calcium carbonate scale in the tower from the lime application of earlier treatment phases.[20]

Continuous monitoring must include wastewater flow, pH, and air flow to assure proper conditions for the design removals. Ammonia NH_3 influent, effluent monitoring is required to determine removal efficiency.

ION EXCHANGE

Ion exchange presents a method for wastewater demineralization by the removal of undesirable cations and anions. Certain resins have the ability to exchange ions from a solution. Under proper conditions the polluting cations are exchanged for hydrogen and the polluting anions for hydroxyl ions.

During treatment,[21] wastewater flows through the resin until it begins to reach its exchange capacity. This is evidenced by breakthrough or reappearance of the undesirable ions in the effluent. Once the exchange bed loses its ion removal effectiveness, treatment is halted while the bed is backwashed to remove dirt, and regenerated. The operational cycle then resumes.

Since ion exchange materials may be contaminated by solids and organics in the wastewater, some prior tertiary removals are recommended.

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[19] *ibid.*

[18] Slechta, A.F. *op. cit.*

[20] FWQA., U.S. Dept. of Interior. *Current Status of Advanced Waste Treatment Processes.* Advanced Waste Treatment Research Laboratory, Division of Process Research and Development. July, 1970.

[21] Eckenfelder, W.W. *Industrial Water Pollution Control.* McGraw-Hill Book Company. 1966.

Studies on the removal of ammonia at the South Tahoe Public Utility District[18] were very encouraging. With an influent of 18 to 28 mg/l, the ion exchange resin showed the capability of treating an average of 400 bed volumes before breakthrough reached 1 mg/l of ammonia nitrogen. With successive regeneration and operation the resin lost little exchange capacity and exhibited no significant organic fouling.

It has been suggested that demineralization is so effective that only a portion of the total wastewater flow need be treated.[19]

Continuous monitoring is important to both the operational and the regeneration cycles. Monitoring influent and effluent presence of the undesirable ion during operation yields both the efficiency of removal and the onset of breakthrough. Through repeated cycling, sufficient data may be accumulated to prepare a curve of ion removal efficiency vs. cumulative volume of flow as treatment progresses toward breakthrough. The curve can be used to determine optimum operational cycle time.

The regeneration cycle requires clean rinsing water and chemicals which may be costly. Monitoring the application of regenerative materials and duration of the cycle can lead to optimal economic operation.

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[18] Slechta, A.F., *op. cit.*

[19] FWPCA U.S. Dept. of Interior. *op. cit.*

SECTION 4
SURVEY OF WASTEWATER TREATMENT PLANTS

Survey forms were sent to the larger wastewater treatment plants across the country. Information was requested on plant processes, the problems of plant operational management and process control, and experience and opinions regarding computer applications. Of the 40 forms sent, 22 returns were received.

The survey attempted to determine:

1. Where are the most critical problems in wastewater treatment?
2. Could continuous monitoring of the *problem* processes help? and
3. Consequently, could digital computer control solve the *problem*?

Among the survey forms received, nineteen contained information on the type of wastewater treatment distributed as follows:

No.	Type
7	primary
1	intermediate
9	secondary
2	tertiary

Plant-flow capacity was reported in million gallon per day (mgd) on 21 forms, as follows:

Number	Capacity (mgd)
3	< 10
4	11 - 50
4	51 - 100
7	101 - 200
1	300
1	343
1	750

In response to the question, *What plant processes require close control and could be improved by continuous monitoring?* one-half of the returns stated *All*. While this answer has merit, it does not convey any sense of priority. Those processes selected are listed in descending order of frequency of appearance on the returns, as follows:

Process	Percent cited
sludge digestion	26
activated sludge	19
chlorination	18
vacuum filtration	14
incineration	13
sludge pumping	10

The question, *What is the most critical problem in plant operational management?* received almost unanimous response on problems with plant personnel. The complaints in descending order were as follows:

Complaint	Percent cited
Unreliability of follow-through	44
Obtaining qualified men	19
Communications	13
Training	12
Lack of process *feel*; sensing changes	12

The question, *What is the most critical problem in plant process control?* received answers attributing the problems to the following:

Causes	Percent cited
External	17
Excess and peak flows	
Industrial spills	
Harmful material entering system	
Variations in influent sewage strength	
Operations	60
Monitoring, but no control	
Lack of timely recognition of malfunctions	
Lack of process flexibility	
Lack of timely data to maintain balance in:	
digesters	
aeration tanks	
Handling and disposal of sludge	
Safe disposal in oceans	
Equipment	23
Pumping	
Density meter calibrations	
Incinerator operation and maintenance	

The question, *Do you use a computer to assist plant operations and management?* was positively answered by ten returns, which is about 40 percent of those received. Only one respondent was applying the computer to an on-line, plant-control operation, influent pumping. The device, used at the headworks of the Deer Island Treatment Plant, Boston, is not a digital computer but a *pneumatic controller* that continuously monitors flow and elevations at three headworks. Pumping is adjusted to maintain predetermined levels in the *shafts* of the headworks in accordance with the signals

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received. The remaining applications were related to plant operations and business services, as follows:

Event	No. of Applications
Operations	8
Plant periodic reporting	4
Maintenance planning and reporting	2
Chemical results	1
Engineering research	1
Services	8
Payroll and personnel accounting	5
Cost accounting and billing	2
Requisitioning	1

The question, *Are you contemplating use of the computer?* was answered positively by twelve respondents, of which four are currently using some computational facility.

No. and contemplated uses (with overlap):
5 automation
1 accounting
10 undesignated

The question, *What are the benefits and disadvantages of computer applications in sewage treatment?* received answers which indicated recognition of the benefits from the following:

Benefit
Data logging
Long term data storage
Process monitoring and alarms
Operational maintenance scheduling
Summary and exception reporting
Inventory control
Quality control analyses
Reduced labor costs
Studies and operational evaluations

Suggested disadvantages included the following:

Disadvantages
Cost
Additional justification
Loss of personalized process *feel*
Too great reliance on sensors (distrust of instruments)
Manual inputs from laboratory testing are too late for control (instrumentation disadvantage)
Need for measurement standards of input variables

A question was posed requesting comment on any special local conditions which would influence computer applications in wastewater treatment. Although the responses varied, some significant opinions appeared in more than one of the returns, as follows:

1. Local regulatory agencies stipulate specific and consistent plant effluent quality. To minimize plant process fluctuations and produce consistent effluent load, process computer control may be necessary.

2. To upgrade the waterway system into which the plant discharges, it is felt that computer control offers an opportunity for closer control of treatment processes by timely adjustments to influent flow rates and sewage composition. This should aid in producing a more satisfactory overall discharge.

3. Lower hardware costs, packaged software at reasonable prices, higher labor costs, and regulatory agency demands for more information all will contribute to a greater use of computers.

4. Increasing costs of operation may lead to automation (forcing function).

5. Cost may be prohibitive to the local administration which sanctions expenditures.

There is no question that computer applications for wastewater treatment processes are receiving a great deal of attention. Among some larger plants, off-line applications are already commonplace, and management is giving strong consideration to computer implementation for continuous monitoring and control. The survey has indicated the pressures on plant management to upgrade effluents and to reduce costs. The returns cited that 60 percent of the most critical problems in plant process control were attributable to internal plant operations involving manpower. Improvements can be realized through higher quality labor, training programs, and better tools, such as continuous monitoring instrumentation and computer controls.

SECTION 5
DATA NEEDS OF REGULATORY AGENCIES

INTRODUCTION

Throughout the country state agencies acquire data on the operation of wastewater treatment plants, chiefly to document effluent characteristics and to tabulate statistics. Most regulatory agencies investigate the pollution of streams and its causes. They foster the promulgation of regulations to establish water quality standards. Whenever a pollution problem is evident, new treatment facilities or improvement of older plants are often prescribed by the regulatory agency. Lack of compliance with regulatory orders may result in rejection of local building permits, suspension of treatment permits, adverse publicity, fines or imprisonment. The Federal Water Quality Acts have engendered the recent adoption of more stringent standards by the states. They have effectively required the upgrading of practically all wastewater treatment plants. Inherent in the new regulations are construction time tables, stream and effluent standards, monitoring and a rigorous program of enforcement.

Industrial waste discharges are subjected to similar abatement regulations. The FWQA estimated that over half the load on public waste treatment facilities originates from industry. Pending Federal guidelines for construction grants stipulate pre-treatment of industrial wastes before acceptance into a municipal sewerage system and the establishment of industrial waste surcharges.

The Federal construction grants program further encourages the development of comprehensive river basin-wide programs for pollution abatement[22]. The percentage of awards for grants are determined to some extent on the degree that new treatment works as well as metropolitan and regional plans fit into a basin-wide approach.

The requirements of both the Federal and State regulatory agencies can be summarized as:

1. High water quality standards for receiving waters, necessitating greater pollutant removals than currently practiced.
2. Strong encouragement of *regionalization* approaches to implement the new removal standards.
3. Rigid enforcement of discharge regulations.
4. Pre-treatment of industrial wastes financed by the industry itself.
5. Increased surveillance with more sophisticated instrumentation and analyses to assure compliance.

REGULATORY AGENCY DATA REQUIREMENTS

The prime concern of the regulatory agencies is the effect of wastewater effluent on the local receiving waters. Stream surveillance is usually accomplished indirectly through the medium of operational reports from the regulated facilities. Report requirements may be comprehensive or minimal in nature. A comprehensive report may include operational data and removal efficiencies from all phases of plant processing as well as information on bypasses and conditions of receiving waters. A minimal report may address itself directly to effluent characteristics. Information is reported on total daily flow, raw influent and final effluent values of pH, settlable solids, suspended solids, BOD, and effluent data on bacterial analysis and chlorine residual.

In many cases the criticism is that very little is done with these reports beyond storage for historical record purposes, especially where state-wide reporting brings in huge quantities of information. The data should be used to observe trends and present information for local plant construction.

Each state has its own reporting system, although data requirements are somewhat similar. It would also appear that standard reporting formats for all plants have not been established for any state.

Samples of reports and forms examined include the following:

1. New York State Department of Health Report on Operation of Sewage Treatment Plant (Form San. 46 10M 2-10-68

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[22] *Federal Register*. Volume 35, Number 128. July 2, 1970.

(7D232)). The form is rigidly defined, very comprehensive and states: "These reports should present a representative picture of operating conditions at the plant so that this Department may be informed and be able to advise and assist the operator in correcting difficulties and maintaining the maximum efficiency of the treatment plant at all times."

2. New Jersey State Department of Health Monthly Operating Report of Sewage Treatment Plant (Form WP-5 Jan 68). This is a basic flexible form with allowance for specifying variables to be measured and laboratory tests.

3. Renton Treatment Plant, State of Washington, report for the state agency is essentially the plant's own monthly report.

4. Hyperion Treatment Plant, Los Angeles, California, report on analyses of plant effluent and digested sludge is tailored to the plant and is comprehensive with emphasis on monitoring of ocean waters and beach conditions.

5. The Pennsylvania State Department of Health has adopted minimum information requirements to evaluate state-wide plant efficiencies. With few exceptions the report requires raw and final effluent values of settlable solids, suspended solids, BOD, and pH, as well as daily flow, population served, relative stability, and chlorine residual.

The new regulations of the Department of Interior published March 31, 1970 require data for evaluating new treatment works construction applications. The FWQA may demand detailed data on the sources of pollution for the entire river basin, the volume of discharge from each source, the character of effluent, the present treatment, the water quality effect, and so on. These requirements may include not only measurement of variables, but extensive analyses as well. It appears that the geographic and physical situation may be the determinant of some of the requirements.

AUTOMATIC CONTROL AND REGULATORY AGENCY DATA

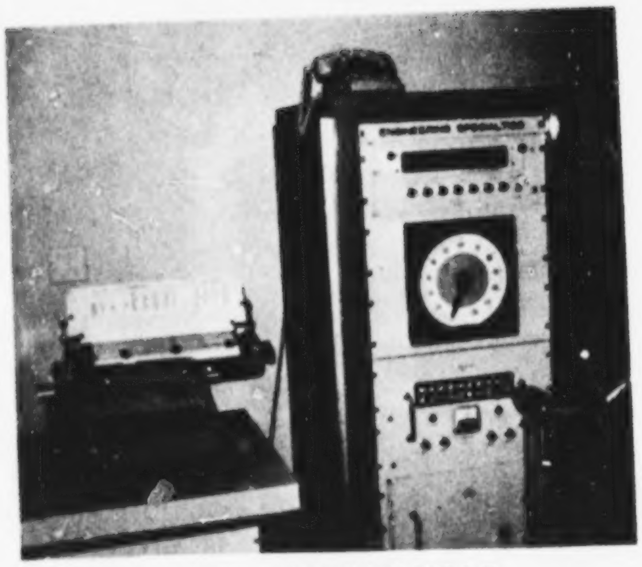
Automatic control and monitoring of wastewater treatment and water quality are fully compatible with the data needs of regulatory agencies. The goals of automated control include both improved data and an improved and more timely reporting process.

A second aspect is that the regulatory agency report can be a direct fall-out of the plant management information system. It can be assumed that any data requested by the state is already a segment of plant reporting or will have to be incorporated into it. Under computer implementation an internal data bank of plant operational information is stored as the basis of automatic control and information processing. Where a computer program system is written to process plant data into a management hierarchy of periodically generated reports, the regulatory agency report is just a part of the system.

Another consideration is the action taken by the regulatory agency upon receipt of the report. The assumption that a great store of state-wide environmental control data is arriving at a central location presents an opportunity for statistical studies and analyses on a large scale basis. The data can be processed into an overview of the status of water pollution control throughout an entire region. Plant effluent variables can be processed into long term trend plots for observation as well as indications for action.

The total approach presented here for a regulatory agency could not readily be accomplished on a purely manual basis because of the volume of information acquired, and the sophisticated statistical nature of the processing. The increased scope of regulatory agency data processing can be directly compatible with computer implementation in wastewater treatment.

The Municipality of Metropolitan Seattle uses a basic data logger device (See Figure 7) to monitor the Green and Duwanish Rivers. The system automatically samples measurements from five water quality analyzers on the rivers in a cycled sequence, usually hourly, and prints them on the typewriter. Some of the variables measured are dissolved oxygen, conductivity, pH, and turbidity. The logger concurrently punches data onto a paper tape which is later fed to offline computers for statistical analysis and reporting purposes.



NOT REPRODUCIBLE

Figure 7. Example of a Data Logger (Water Quality Monitoring at Metropolitan Seattle, Washington)

Another water resource management approach being given serious consideration is the establishment of basin-wide water quality monitoring systems. "The use of electronic data processing techniques as a management tool becomes necessary for the control of water pollution because the magnitude of the problem is too great to be controlled manually".[23] Such a monitoring system should be designed to provide immediate, accurate information on the extent, nature and movement of pollutants at remote stations. Its objectives should include provisions for:

1. Constant surveillance of water pollution and its sources
2. Warning networks
3. Information on fishkills
4. Assistance in further development of water quality standards and regulations
5. Exploitation of the water resource
6. Means for analyzing special problems
7. Aid in evaluating local water pollution control problems

The physical system includes a network of remote stations containing automatic sampling and continuous water quality monitoring equipment. Data are transmitted to a central station which will receive and process the signals, and may then calculate and display the results. The fundamental premise of the system is continuous monitoring with direct connection to an electronic computer.[24] In this manner the system may *track* the hydraulic flow of a pollutant as well as its identity. Pollution sources can result from continuous flow, diurnal patterns, seasonal variations and instantaneous releases such as storm overflows or industrial spills. Continuous monitoring may identify the temporal nature of the flow. An alarm system associated with continuous monitoring can signal an operator's attention at the central site or at some *watchdog* headquarters, should the presence of a toxic substance or abnormally high pollutant appear.

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[23] Ellis, Eddie E. *The Application of Electronic Data Processing Techniques to Water Pollution Control.* Florida Air and Water Pollution Control Commission.

[24] Schieber, John R. *Continuous Monitoring, Chemical Engineering.* Deskbook Issue. April 27, 1970.

SECTION 6
GUIDELINES FOR COMPUTER IMPLEMENTATION

INTRODUCTION

Implementing a digital computer into an operational plant presents a challenge to all disciplines involved in plant management and operation. The decision to investigate the possibilities of automation is to embark on long range, dedicated planning by management. What are the considerations? First, you must know your plant and its system, where administration and communication begin and end, the physical boundary, the technology operations and control. These form the basis for the technical justification of computerized process control. Equally important are the economics relevant to computer implementation. Can sufficient sources and amounts of cost improvement be found to pay for the automation system for either existing plants or those in the design stage? Can economies of design, scale and operation be effectuated? What are the tradeoffs of computer costs versus savings in manpower, materials and plant space?

Improvement of product quality cannot be discounted. Greater percentage removals through better process control via computer can be translated into capital costs for newly designed or existing plants. A small guaranteed increase in percent removal accomplished through automation will more than justify the expenditures for the control system.

TECHNICAL JUSTIFICATION FOR COMPUTER CONTROL

Recent technical literature proliferates in discussions of computer control of industrial processes. Some criteria[25] have been suggested as comprising a basis for technical feasibility of computer control. While they are considered in context to industrial, profit-making operations, these criteria are applicable to wastewater treatment. The status of the process and its suitability with regard to automated operation are examined. Questions are asked whether it is worth the expense, time and manpower to implement a computer. In essence, automation should not be considered where production is smooth, steady-state, free of disturbances, relatively simple and operating at high efficiency. This is not the case in wastewater treatment. Influents are variable in flow and quality. Process stages are not optimized, so that greater percentage removals are possible with proper control. Effluent improvement and overall efficiency can be enhanced. Process disturbances do occur and can have dire effects.

With population and industrial growth, regulatory agency requirements are becoming more stringent to preserve the quality of our environment. These increasing removals are taxing the capability of present day plants both in capacity and controllability. New sophisticated controls and treatment procedures must be implemented to accommodate the demands of an affluent society with a high standard of living. Computer control can offer an upgrading of operations.

Once the basic premise of automated process control is accepted, then the feasibility of computer implementation can be considered. Can the process be automated? Can the computer communicate with the process? Are models or systems for this process control application available, or can they be developed? What is the cost? What is the degree of improvement?

Process Improvement

One benefit to be expected from computer control is some improvement in the quality of the throughput and management of the process. The survey of plant management in Section 4 disclosed the need for improvement in the following general areas:

1. Balance in the critical treatment phases of:
    a) Activated sludge,
    b) Anaerobic digestion, and
    c) Sludge conditioning,
2. Accurate plant data and its timely implementation, and

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[25] Scrimgeour, J.H. *How to Assess the Economic Justification for Process Computer Control.* Canadian Controls and Instrumentation. Canadian General Electric. April, 1968.

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3. Plant operational and maintenance personnel.

As an example of improvement in plant management, the City of Philadelphia can be cited for an effective, well maintained computer program for information reduction. Implementation of the NELOG[26] program, a management information system for the Northeast Water Pollution Control Plant, has:

1. Reduced the time required for record keeping,
2. Minimized human errors,
3. Eliminated long, cumbersome data sheets,
4. Eliminated tedious hand calculations,
5. Permitted detection of *out-of-spec* input data,
6. Permitted standard deviation computations for all data on a daily basis,
7. Added more calculated parameters than the manual version of the original report,
8. Reduced manual processing needs by almost a half man-year per year for original report,
9. Standardized procedures for data acquisition,
10. Initiated a data bank for model building,
11. Initiated simulation and engineering studies, and
12. Established a basis for and major step toward closed loop control.

The computerized version of NELOG, of which an excerpt is shown in Figure 8, has permitted more calculations and data checks which were not possible with the original manual version. The additional features are valued at approximately three man years.

Another example of process improvement via computer implementation is the electronic data logger monitoring system at the Los Angeles Hyperion Wastewater Treatment Plant. This system monitors operation of ten electric power generators which supply the plant and air blowers. The engines are fueled almost entirely (94 percent) by gas from the digester system. The logger generates operational parameters on two typewriters periodically with *out-of-spec* values printed in red to alert the operator. There are output and data controls such as frequency of printing, arbitrary selection, and output hold except for the alarm condition. Currently there is no feedback control to engine operation. The logger has eliminated manual monitoring, thereby yielding a manpower saving of three men, their overhead and backup and "does a better job".

Disturbances in Processing

If all processes are steady-state and function smoothly over long periods of time, then computer control may be unnecessary. If computer assistance is desired, off-line computer calculations may be generally sufficient to define the control requirements. However, in a secondary sewage treatment plant, operations are generally vulnerable to disturbances with regard to:

1. The unpredictable nature of the plant influent in both quality and quantity, and
2. The critical problem of maintaining healthy hordes of hungry organisms for biological treatment.

Some specific plant disturbances are cited:

1. Storms can raise the influent flow well beyond plant capacity
2. A toxic spill entering the plant can kill the bacteria and upset the biological activity
3. A power failure will cease pumping, aeration, clarification, etc.
4. Digesters are frequently reported as going *sour*, or failing, and it can take weeks for the unit to return to normal.

With continuous monitoring of the influent flow and critical plant processes, imminent changes can be recognized, and corrective action taken before the disturbances cause critical conditions.

Process Complexity

Secondary treatment is complex. A well-monitored plant requires continuous measurement of variables during each stage of the treatment process. The Northeast Water Pollution Control Plant at Philadelphia with a design capacity of 175 mgd, logs approximately 400 measurements per day, which aid in the operation and maintenance of this plant.

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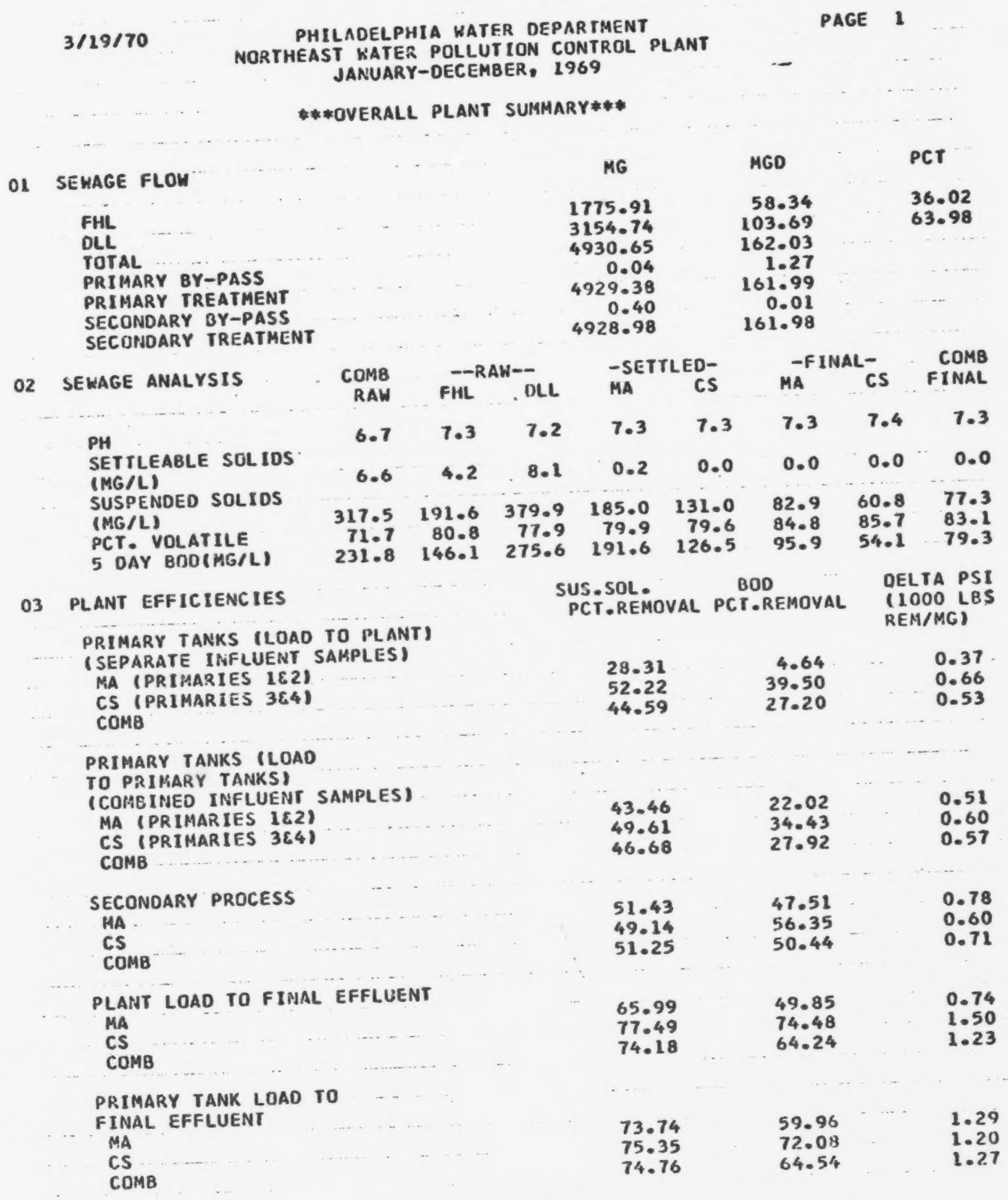
[26] Guarino, C.F. and J.V. Radziul. *Data Processing in Philadelphia*. Journal Water Pollution Control Federation. August, 1968.



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3/19/70              PHILADELPHIA WATER DEPARTMENT                      PAGE  1
                NORTHEAST WATER POLLUTION CONTROL PLANT
                        JANUARY-DECEMBER, 1969

                       ***OVERALL PLANT SUMMARY***

                                                MG          MGD          PCT
01  SEWAGE FLOW
                                             1775.91        58.34        36.02
     FHL                                     3154.74       103.69        63.98
     DLL                                     4930.65       162.03
     TOTAL                                      0.04         1.27
     PRIMARY BY-PASS                         4929.38       161.99
     PRIMARY TREATMENT                          0.40         0.01
     SECONDARY BY-PASS                       4928.98       161.98
     SECONDARY TREATMENT

                                                 -SETTLED-       -FINAL-      COMB
02  SEWAGE ANALYSIS       COMB     --RAW--                                    FINAL
                          RAW     FHL    DLL     MA     CS      MA     CS

     PH                    6.7     7.3    7.2    7.3    7.3     7.3    7.4     7.3
     SETTLEABLE SOLIDS
     (MG/L)                6.6     4.2    8.1    0.2    0.0     0.0    0.0     0.0
     SUSPENDED SOLIDS
     (MG/L)              317.5   191.6  379.9  185.0  131.0    82.9   60.8    77.3
     PCT. VOLATILE        71.7    80.8   77.9   79.9   79.6    84.8   85.7    83.1
     5 DAY BOD(MG/L)     231.8   146.1  275.6  191.6  126.5    95.9   54.1    79.3

                                         SUS.SOL.          BOD         DELTA PSI
03  PLANT EFFICIENCIES                 PCT.REMOVAL    PCT.REMOVAL    (1000 LBS
                                                                      REM/MG)
     PRIMARY TANKS (LOAD TO PLANT)
     (SEPARATE INFLUENT SAMPLES)
      MA (PRIMARIES 1&2)                  28.31           4.64          0.37
      CS (PRIMARIES 3&4)                  52.22          39.50          0.66
      COMB                                44.59          27.20          0.53

     PRIMARY TANKS (LOAD
     TO PRIMARY TANKS)
     (COMBINED INFLUENT SAMPLES)
      MA (PRIMARIES 1&2)                  43.46          22.02          0.51
      CS (PRIMARIES 3&4)                  49.61          34.43          0.60
      COMB                                46.68          27.92          0.57

     SECONDARY PROCESS
      MA                                  51.43          47.51          0.78
      CS                                  49.14          56.35          0.60
      COMB                                51.25          50.44          0.71

     PLANT LOAD TO FINAL EFFLUENT
      MA                                  65.99          49.85          0.74
      CS                                  77.49          74.48          1.50
      COMB                                74.18          64.24          1.23

     PRIMARY TANK LOAD TO
     FINAL EFFLUENT
      MA                                  73.74          59.96          1.29
      CS                                  75.35          72.08          1.20
      COMB                                74.76          64.54          1.27
```

Figure 8. Excerpt From the Computer Generated NELOG Summary Report (Northeast Water Pollution Control Plant, Phila., Pa.)

The degree of complexity in both monitoring and control is too great for one operator to respond to all plant conditions. As a tool to tie into monitoring and control, the computer can process data, make decisions and generate commands well within the sensitivity of the wastewater treatment process. Complex systems with multiple stations for sampling and feedback of data are well within the state-of-the-art of process computer applications. The lack of automated wastewater treatment plants must be attributed to other reasons. The control capability of computers has been demonstrated in other bulk processing industries such as petroleum refineries, steel refineries and chemical plants.

Automatic Operation

The questions of process improvement, disturbances and complexity have been discussed. The system now must be examined for suitability to computerized operation. One important conversion to computer operations is data logging and management reporting, the improvement of data collection and recording for better operator control.

Many analog loops exist in sewage treatment[27]. Some are:

1. Air flow regulated by dissolved oxygen measurements,
2. Return sludge proportioned back to the aeration tanks to maintain a desired mass-to-food ratio,
3. Post-chlorination regulated automatically on the basis of flow and residual chlorine control,
4. Variable speed wastewater pumping to maintain more uniform flow to the treatment process,
5. Bar screen clearing on the basis of increased head loss
6. Level sensor to determine rate of pumping into primary tank,
7. Sludge density to determine when to pump from primary tank, and
8. Pumping station control of number of pumps stepped on or off according to flow requirements.

The existence of local analog loops indicates that local hardware can be made compatible with digital computer closed loop control.

Despite the potential of closed loop control, the human factor is still very strongly present in the wastewater treatment plant, and the operator is still the most important monitor and decisionmaker.

Computer-Process Communication

Computer control requires considerable communication equipment to tie the computer to the process for both monitoring and feedback control. Internally the computer central processor looks to core memory for its stored data. If a routine is called to operate on information sampled from the plant process, then that information will have been sampled, brought to the computer, converted to input data, read in and stored for digital processing.

Communication equipment is reliable and converters, remote scanners, recorders, telemetry and telephone lines. Any variable that can be measured can be incorporated into a centralized control system. But, not every pertinent variable can be automatically and continuously sensed as cited in Section 1.

continuously sensed as cited in Section 1.

Sensors as probes or electrodes used in wastewater treatment are subjected to a hostile environment. They get coated and attacked by the materials in the stream flow. Satisfactory operation of sensors, however, can be maintained by adequate preventive maintenance measures[28].

Process Models

Closing control loops or replacing analog with digital loops requires a computer stored process model to interpret the sampled variable and to generate a control signal response.

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[27] Ryder, Robert S. *Automatic Control for Smaller Water and Wastewater Facilities.* Proceedings, Ninth Sanitary Engineering Conference. University of Illinois College of Engineering. February 7-8, 1967.

[28] Puzniak, T.J., W.F. Benusa, and J.A. Condron. *Mobile Water Conservation Laboratory.* Preprints, 16th Annual Analysis Instrumentation Symposium. May 25-27, 1970

The relationships among the variables in each treatment process must be defined and implemented into the computer software as control algorithms. They may result from mathematical models based upon scientific theory of treatment, from empirical relationships based upon regression analysis of plant data, or from both.

The Federal Water Quality Administration is sponsoring a study of mathematical modeling of wastewater treatment processes[29]. Virtually all phases of conventional secondary treatment are being modeled with further work continuing into advanced and tertiary treatment.

At some treatment plants correlation studies are being performed to statistically uncover relationships among variables of sufficient significance to be suitable as control algorithms. However, the predictive capability of a statistical relationship for one plant may be of little value to another plant treating different waste. Each plant should make its own study based upon its own data to evolve its specific empirical relationship for a particular control.

LABOR ALLOCATION AND MAINTENANCE

One of the most critical problem areas in wastewater treatment is the cost and quality of labor. Competent personnel are difficult to find, and labor costs keep rising. In a sewage plant labor is stigmatized, and few care to work there. Some proponents say that those that do should be paid premium wages. The reduction of manual labor requirements in a wastewater treatment plant via automation can yield economic significance and add prestige to this industry.

Those areas which are designated as under computer responsibility will become tied into the system for automatic monitoring, reporting and control. The respective changes will be reflected throughout the system as reductions in operational labor requirements in such functions as equipment adjustments, monitoring, data logging and report preparation.

Under automated operations, the emphasis of labor applications will shift from equipment operation to equipment maintenance, thus requiring a higher quality worker.

The response from the APWA survey (Section 4) includes direct references to the labor and maintenance areas as sorely in need of improvement. Specific recommendations were noted with regard to standardized, well documented maintenance procedures assisted by computer stored records.

An available computer presents the opportunity for automatic storage and processing of the files for equipment maintenance. Such computer stored files can aptly supplement a plant-wide comprehensive program of preventive maintenance. Management can establish a new program of maintenance records on all major equipment with designated functions to be performed at specified intervals for optimum operational performance and life. Some of the operations of computer stored preventive maintenance files may include:

1. Daily listing of required maintenance work,
2. Daily file updating of work performed,
3. Reminders for work falling behind, and
4. Special studies on maintenance cost and equipment depreciation.

In short, computer control offers a potential three part economic advantage in:

1. The elimination of some labor operations,
2. The improvement of equipment maintenance via better labor utilization, and
3. Centralized, computer processed preventive maintenance files.

The presence of a sophisticated computer complex and its associated controls will demand higher calibre plant personnel to operate and maintain the equipment. Labor standards and grading will correspondingly have to be modified upwards. It will be necessary to train plant operators and maintenance personnel to work with the computer controlled system. This training period is usually of short duration, relatively inexpensive and provided by the equipment manufacturer.

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[29] Smith, R., R.G. Eilers, and E.P. Hall. *Executive Digital Computer Program for Preliminary Design of Wastewater Treatment Systems.* Water Pollution Control Research Series Publication No. WP-20-14. Cincinnati, Ohio. August, 1968.

As the system evolves, some reprogramming may also be necessary to optimize computer operations. This should be performed in-house or by the original programmers and should be economically feasible, yielding improved operation at reduced costs.

SOURCES OF ECONOMIC JUSTIFICATION FOR COMPUTER CONTROL

Implementation of computer control can be a costly, time-consuming and critical undertaking. Economic justification must be sought to determine how automation costs can be self-liquidating, if they are to be borne by the general public. Under commercial production, the improvement of a few percent in product output and a more efficient use of raw materials and power are expected to pay for the computer complex and the systems engineering costs. In wastewater treatment the product is not an item to be marketed, unless direct reuse is contemplated. The pay-off can be a social investment in effluent quality improvement and the associated abatement in pollution of the receiving waters. Internal factors should be examined for an economic return, such as labor savings, improved maintenance, reductions in power and material usage, and less costly control equipment.

Many areas of plant processing can be cited as capable of yielding economic return under computer control. A true economic evaluation can only be resolved by plant management and supervisory personnel because they are familiar with and responsible for the day-to-day operation, the changes to be put into effect under computer implementation and the associated influences on operational costs.

In general, for existing plants automation can defer expansion and the consequent capital costs. For new plants, automation offers increased processing capability for the same size or allows smaller plant construction, thereby permitting savings in land needs and capital costs.

Higher Quality Product

The ultimate goal of any wastewater treatment plant is to produce the highest quality effluent achievable, consistent with its design and good operating procedure. Where plant removals have been significantly upgraded, the surrounding area can realize some economic returns from the correspondingly upgraded quality of the local receiving waters. These may be in the form of renewed recreational activity such as fishing and boating, improved influent for a water treatment plant downstream and new lands for development. The state and local governments could realize a sizeable income from increased taxables of the land around the streams.

Operational Efficiency

Computer assisted plant control should permit plant operation at higher removal efficiencies with less variations. Consider a hypothetical case of a plant operating in the percent BOD removal range of 75 to 90 with an average of 85. If the percent BOD removals could be raised to a range of 90 to 95 with an average of 92.5, the BOD loading to the receiving water would be halved[30]. Consider the BOD reduction and stream loading per 1000 pounds BOD influent in Tables 2 and 3.

TABLE 2. LOOSE TREATMENT CONTROL OF BOD

BOD	Percent removal	Pounds removed	Pounds to stream
min.	75	750	250
max.	95	950	50
ave.	85	850	150

TABLE 3. IMPROVED TREATMENT CONTROL (WITH COMPUTER) OF BOD

BOD	Percent removal	Pounds removed	Pounds to stream
min.	90	900	100
max.	95	950	50
ave.	92.5	925	75

Although a plant may be deliberately designed for a higher capacity than normal design to accommodate wide variations of influent quality and quantity, the capability of closer automated control may deem the added capital costs unnecessary. As cited above, it should be possible to operate the plant closer to its designed maximum efficiency with a lesser degree of variation.

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[30] Andrews, John F. *Dynamic Modeling and Simulation of Biological Processes Used for Waste Treatment.* Environmental Systems Engineering Dept., Clemson University. June 30, 1969.

More efficient plant control should lead to reduced usage of input materials such as compressed air, chemicals and fuels and consequent reduced in-process inventory and warehouse space.

Improved plant control should result in more efficient usage of electrical energy. For instance, automatic monitoring of total power usage can cause an alarm whenever power consumption is approaching that peak demand which raises the power rate for the month. At the warning alarm, steps can be taken, if possible, to prevent the peak from occurring by shutting down some less essential equipment. On the other hand, should the peak have occurred, then during the ensuing period of high rate charges, the computer can generate control rules to make the best use of the extra power charge.

Digital Versus Analog Loops

Closing control loops via the digital computer can yield a saving through elimination of the hardware associated with analog devices, such as the analog-controller, its panel set-up and alarm equipment. It has been suggested: "the economic crossover point between conventional analog instrumentation (both electronic and pneumatic) and direct digital control lies somewhere around 100 loops".[31] Yet, cost alone is an insufficient basis for comparison. Consideration must be allotted to some of the benefits of digital over analog control to which it is difficult to assign an economic value, such as:

1. Operational improvement,
2. More easily implemented changes in control conditions,
3. Sampling, storage and computational operations with the control data, and
4. Remote availability of data.

It is possible with a digital, closed loop to make subtle *custom* changes to the system via changes in the program. The control strategy can be arbitrarily modified almost at will without requiring equipment additions or changes. The control engineer is not constrained to working out the best trade-off with the available analog products.

By-Products

As stated previously plant effluent is usually not a product for sale. High quality is sought to prevent pollution of the receiving waters. With sufficiently high removals, it also has been possible to find some economically useful applications of the water other than merely losing it to the local streams. Some examples of such water reclamation[32] from wastewater treatment plants are cited:

1. Washing tanks and watering the plant lawns and shrubbery,
2. Ground water recharging or control of salt water intrusion,
3. Industrial use notably for cooling,
4. Agricultural use in irrigation and watering of golf courses, and
5. Recreational use through a series of treatment ponds.

Water reclamation is a growing economic consideration in water resources management. With increased water needs in the future the importance of water reclaimed from municipal return flows must begin to look more like a resource rather than a waste.

Other by-product yields from wastewater treatment which may b epossible sources of economic return are:

1. Digester gas to heat the plant, to heat sludge entering the digesters and to fuel the power generator engines,
2. Dried sludge for sale as fertilizer, and
3. Composting of sludge for use as a soil conditioner.[33]

Intangible Benefits

The availability of the computer offers a tool for engineering studies and research. Monitoring and control data retained in computer storage can be periodically processed to generate new parameters for the on-line control functions. New approaches to system operation can be tested in simulation studies with the computer. The day-to-day operation is its own evaluation of effectiveness. The computer simultaneously yields information and avails itself for modifications of its programmed routines where the functions show a need for improvement.

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[31] *Forecast, Evolutionary and Revolutionary Trends in Process Control.* Chemical Engineering. January 13, 1969.

[32] McGaughey, P.H. *Engineering Management of Water Quality.* McGraw Hill Book Company. 1968.

[33] Clark, J.W. and W. Viessman. *Water Supply and Pollution Control,* p. 453. International Textbook Company. Scranton, Pa. 1965.

In these days of great concern over pollution abatement, a plant that does its job well becomes an acclaimed asset to the community.

Via improved, more efficient operation, monitoring and maintenance under computer control, equipment can be expected to last longer, thereby allaying capital expenditures.

The revived importance and recognition of the critical nature of pollution control has served to attract additional capable engineers into plant operation. These progressive engineers are already applying experimental approaches to treatment and are eager to investigate computer control. This next dimension in treatment practices will increase the challenge of a new, sophisticated technology and further enhance the attraction of highly capable engineers.

PRELIMINARY INFORMATION NEEDS FOR COMPUTER CONTROL

Some assessment of the operational load on the computer occasioned by process control as well as desired off-line operations should be sought.

The Plant System and Computer Responsibility

An evaluation requires a thorough knowledge of the total plant, identified as a system. Management must define the boundary of the treatment system, which may go beyond the physical plant to include the sewer network lines or portions of them and the receiving waters, to whatever vicinity they are affected by the effluent. Where gaseous effluents and odors are a possibility, the surrounding air should come within the system boundary.

Once the treatment system and its boundaries are defined, the overall area of computer implementation and responsibility within that system can then be determined. Management must judge the extent of functional responsibility and area of control to be encompassed by the computer, or left to supervisory control by humans.

System Inputs and Outputs

The boundary of computer responsibility is delineated for inputs and outputs of material, energy and manpower. These variables relate directly to the objective of highest quality effluent at minimum consumption of energy, material and manpower within the constraints of the wide variations in quality and quantity of influent.

In the wastewater treatment plant, inputs have the following influent identification: flow (mgd), temperature, suspended solids concentration, biochemical oxygen demand and concentrations of other contaminants. As the major stream flow, the influent identifies the sewage strength to be processed, and therefore determines the requirements on other inputs which are utilized in the treatment process. These minor stream flow inputs may include power, chemicals, water, air flow and gas. Outputs from the plant can include the effluent to the receiving waters characterized by the same stream flow parameters as well as chlorine residual. Other outputs include sludge and gas generated.

A clearly delineated definition of system inputs and outputs under jurisdiction of the computer helps to determine the goals necessary to optimize operations and the functions to be performed.

Operation Review

The approach to plant process automation must be accompanied by an investigation of all facets of operational management and processing functions. All too often reporting forms become obsolete; the report hierarchy changes; new *hand-made* forms are invented, and standardization collapses. A modernized, up-to-date standardization and streamlining of information processing must be established.

Each process should be investigated to develop a logical control procedure based upon experience and quality engineering practices. Measurements, decisions, computations, whenever involved should be entered as steps in an operational control procedure. Such activities when documented become an empirical basis for a standardized approach to computer control.

A complete review of maintenance procedures should be performed to establish a schedule of preventive maintenance functions and a standardized log for the work.

A preliminary order must be achieved and documented, guided by economy and efficiency before steps can be taken toward computer implementation. This approach leads to a studied awareness of plant functions by management and allows a better communication with the automation engineers.

MATHEMATICAL MODELING APPLICATIONS

Mathematical Modeling and Simulation

In the application of computers to control of a physical process, the loop is eventually closed through use of a mathematical model of the process. The mathematical model can be defined as a logical-mathematical representation of a concept, system or operation. The model operates on the measured variables and calculates the proper values of adjustable variables to actuate the required control. As an abstraction from a real world situation, the mathematical model is an attempt to simplify the existing complexities for each of the control computations, while simultaneously generating data of sufficient accuracy to represent the real system in required applications.

The word simulation occurs in association with mathematical modeling. There is a distinction in definitions although the two terms complement each other. The mathematical model is the tool, the actual mathematical-logical system, the program built for a digital computer. The applications to which the model is subjected comprise simulation. This is particularly true in digital computer programmed models where the test cases operate the mathematical model under varying simulation conditions.

Mathematical models can be used off-line in a strictly digital simulation atmosphere to study a physical system. The constants can be changed to represent different versions of the system, and the variables can be incremented to modify the operating conditions. For example, in a wastewater collection system some of the constants are shape of conduit, length of conduit, slope of conduit and friction factor. If any of these factors are changed, the represented physical system, i.e., the mathematical model, is changed. On the other hand, flow supplies, branch inputs and pump operations, are variables. When these values are changed, and in a real hydraulic system they change continually, the original system remains the same, but it has been subjected to different operating conditions. So, in a programmed hydraulic collection system, a given model is entered once into the computer, while test cases or simulation conditions on the model may be run ad infinitum.

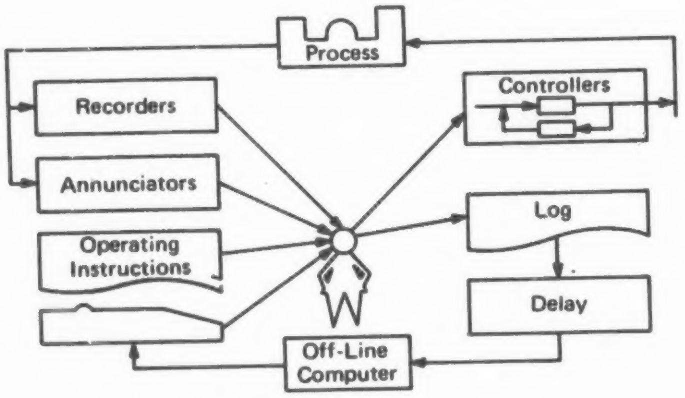
The value of digital simulation lies in the flexibility of operation. A simulated system can be put through its paces and operated under all variations of normal and extreme conditions. The system can be checked out and evaluated, and never leave the computer. Many questions can be asked during simulation. The validity of the answers is a function of how well the model represents the true system or prototype. Information that can be acquired during operation of the mathematical model includes:

1. Sensitivity and range of adjustable variables,
2. Variables most suitable for control,
3. Interactions among variables, beneficial or detrimental,
4. Variable combinations applicable to control,
5. Sources of disturbances and their corrective action,
6. Operational effectiveness and improvement,
7. Required variables and accuracy.
8. Superfluous variables,
9. Potential for model improvement, and
10. Response to simulated emergencies.

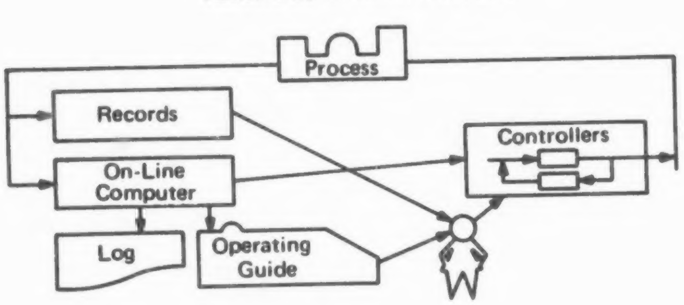
The information acquired during the simulation runs may be used to design new systems or to develop models for automatic control.

With plant operations simulated, the computer will allow an engineer to experiment beyond anything that would be tolerated by management in the real plant. Each subsystem can be exercised through the widest variations of its parameters to determine the best operational range. Furthermore, the opportunity exists through modeling to apply optimization techniques to an objective function, such as cost minimization, and its constraints.

Once a fully off-line digital simulation model has been checked out, it is adaptable for use in a process control, on-line loop. Figure 9 illustrates the relationship of the computer to a control process on an off-line and an on-line basis. Note that the loop can be closed without the man when the computer is on-line.



a. Process Operation
Assisted by Off-Line Computer



b. Process Operation
Assisted by On-Line Computer

Figure 9. Off-Line vs. On-Line Computer Control

Mathematical Modeling for Wastewater Treatment Processes

One of the areas cited as needing further development in computer control of wastewater treatment is mathematical modeling. Interest is strong, and much work is being done from at least two directions, the empirical (often referred to as *practical*) and the theoretical approach.

The empirical approach is being taken by many researchers in wastewater treatment plants. In a well-monitored plant, data are available for a great variety of variables, many of which are directly related to process control. With statistical analysis and the digital computer, these can be subjected to correlation studies. Where indications of high correlation appear, the data can be processed by a regression analysis, such as least squares, to generate a functional relationship. This new function can serve as the approximate or empirical law governing the variations of a dependent variable with one or more independent variables and can therefore be considered a mathematical model for the particular plant process. Where empirical relations are used, they are properly referenced as backed by experimental verification.

In this method it is also very useful to plot, if possible on an automatic plotter tied into a digital computer, all the original data points as well as the generated curve. The picture enhances the *feel* for the new function. In Figure 10 are shown cases of data points plotted along with the computer generated straight line function. In Figure 11 two variables are plotted versus time to demonstrate their interdependence.

While the above empirical approach seeks a relationship among data purely for data's sake with no guidance except what is extracted by the statistics, the alternate approach to mathematical modeling seeks a theoretical foundation to the relationship. All parameters involved are identified and assigned dimensions. Physical and chemical laws are cited as the basis for formulas among the variables.

The Federal Water Quality Administration has been sponsoring the development of mathematical models for wastewater treatment[28] to fit a system approach framework. The models are for specific treatment processes, such as a primary settler, digester, trickling filter, etc. The models operate on a stream vector of wastewater flow

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[28] Smith, R., et. al. *op. cit.*

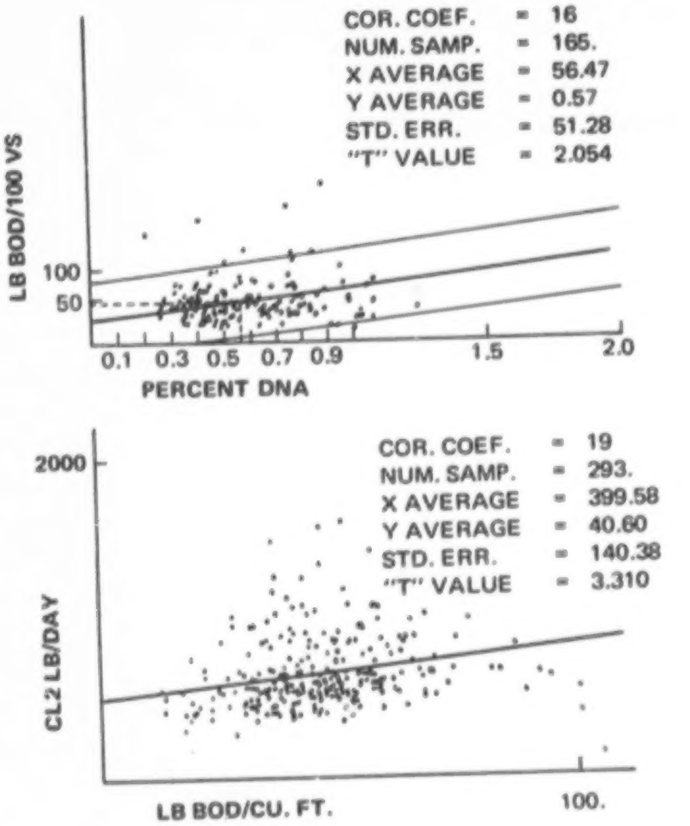

Figure 10. Computer-Assisted Straight-Line Regression Analyses at Metropolitan Seattle, Washington, Basis for Development of Empirical Laws Relating Plant Variables.

descriptive parameters, such as volume flow, solid BOD, dissolved BOD, total suspended solids, volatile suspended solids, etc. For a given process a stream vector is numerically defined, enters the treatment component, is processed through the model equations and is converted for exit from the treatment component according to the calculated removals. By associating a sequence of treatment component models, with travel and conversion of the stream vector tying the processes together, the unit process models can be assembled into simulated plants. The computer program system operated under control of an executive routine also computes the cost of operation and an evaluation of performance.

Thus, an arbitrary assemblage of wastewater treatment unit processes can be fabricated into a plant model. The model can then be subjected to a series of simulated wastewater conditions with variations in flow, contaminants and relative strength of contaminants. Each case will generate an evaluation with respect to cost and contaminant removal effectiveness of the individual processes and the system as a whole. Costing refers to computation of capital costs, debt amortization, plant operation and maintenance "... with a fair degree of reliability".[34] While the emphasis is on design analysis in these FWQA studies, further investigation could reveal their applicability to plant control as well.

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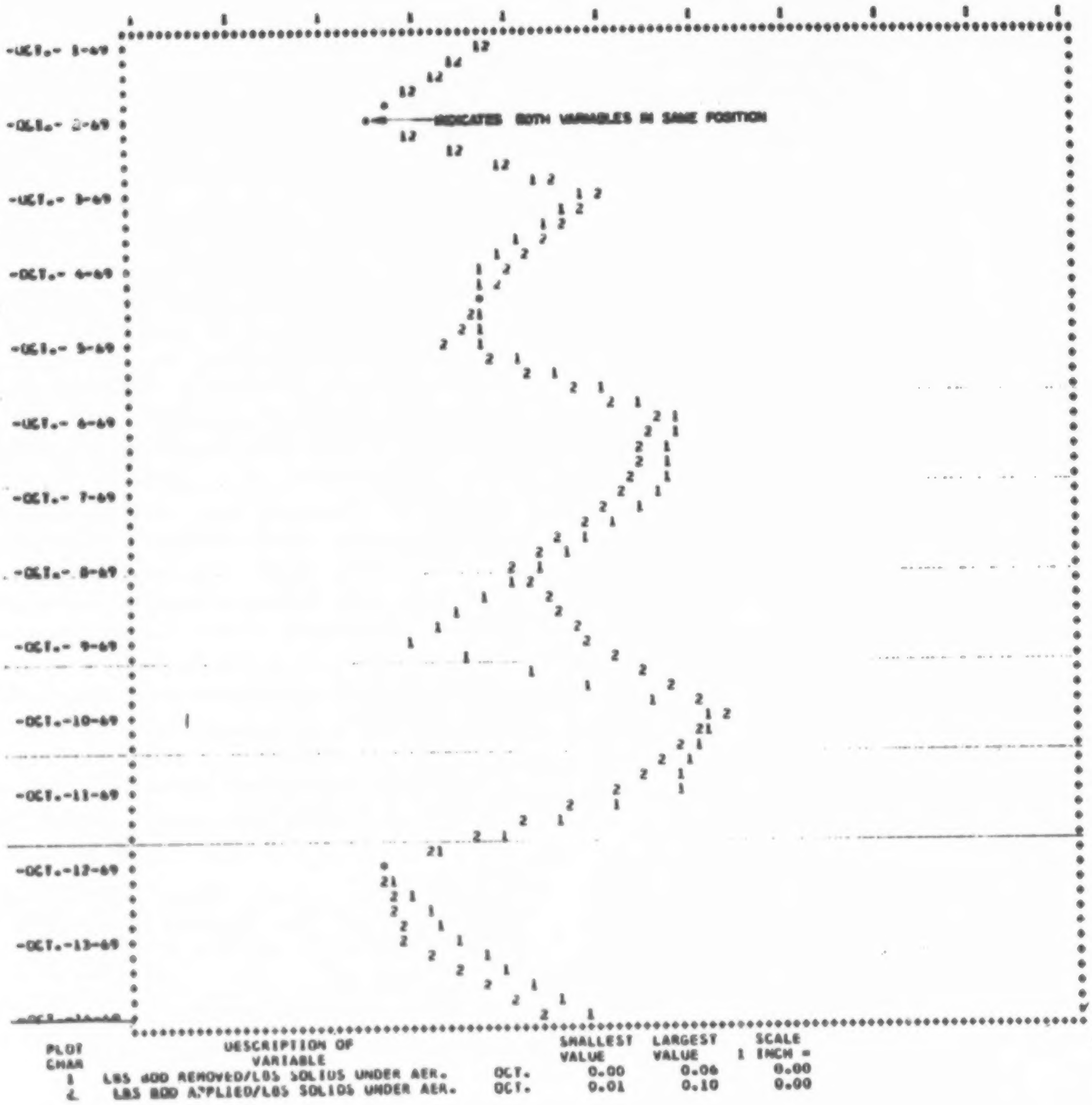
[34] Smith, Robert. *Preliminary Design and Simulation of Conventional Wastewater Renovation Systems Using the Digital Computer.* U.S. Department of Interior, FWPCA No. WP-20-9.



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PLOT          DESCRIPTION OF                              SMALLEST   LARGEST    SCALE
CHAR             VARIABLE                                  VALUE      VALUE   1 INCH =
  1   LBS BOD REMOVED/LBS SOLIDS UNDER AER.     OCT.        0.00       0.06      0.00
  2    LBS BOD APPLIED/LBS SOLIDS UNDER AER.    OCT.        0.01       0.10      0.00
```

CS — ABBREVIATION FOR CONTACT STABILIZATION

Figure 11. Automatic Plot of Two Variables vs. Time. (Generated From a Computer Stored Data Bank Indicates Correlation of BOD Removal vs. BOD Input of Contact Stabilization System at Philadelphia.)

SECTION 7
MEASURED STEPS TOWARD PLANT AUTOMATION

INTRODUCTION

The approach to wastewater treatment plant automation is seen as a coordinated effort to establish computer control of plant processing and management information. Careful planning and study are required to incorporate into a functioning plant as powerful and critical a tool as the digital computer. The technologies required necessitate a team of plant management associated with expertise in wastewater treatment processes, instrumentation, plant hardware, communications and process computer application.

Computer implementation can be designed into new plants, existing plants or expanding plants (such as primary to secondary). A preliminary automation study can develop the required automation steps for compatibility with the particular situation.

Despite the lack of both treatment knowledge and adequate instrumentation in some areas, there are sufficient workable applications to encourage automation. The challenge can be met and solved once the effort is made. A series of measured steps are presented toward the goal of automated plant control. Each is designed to yield new confidence in the system while setting the stage for the next step. These steps are briefly introduced in the following four paragraphs.

Systemize Plant Data Handling

Allow a digital computer to process all the manual work for plant reporting and the retention of records for equipment maintanance. Other areas of *off-line* computer application include engineering design and analysis, inventory control, payroll and accounting.

Improve Instrumentation and Supervisory Control

Where possible, implement improved, automatic monitoring instrumentation compatible with computer inputs. Centralize plant communications, reporting and supervisory control at a conveniently located supervisory panel and associated computer console.

Convert to Automated Operation

Allow the computer to assist in decision-making by implementing some of the basic operator logic of supervisory control into the computer. Initiate a study (based upon the improved data collection) to develop mathematical relationships among the measurements involved in closed loop control. Test the control methods *off-line* (modeled in a computer) to prove them out.

Closed Loop Control

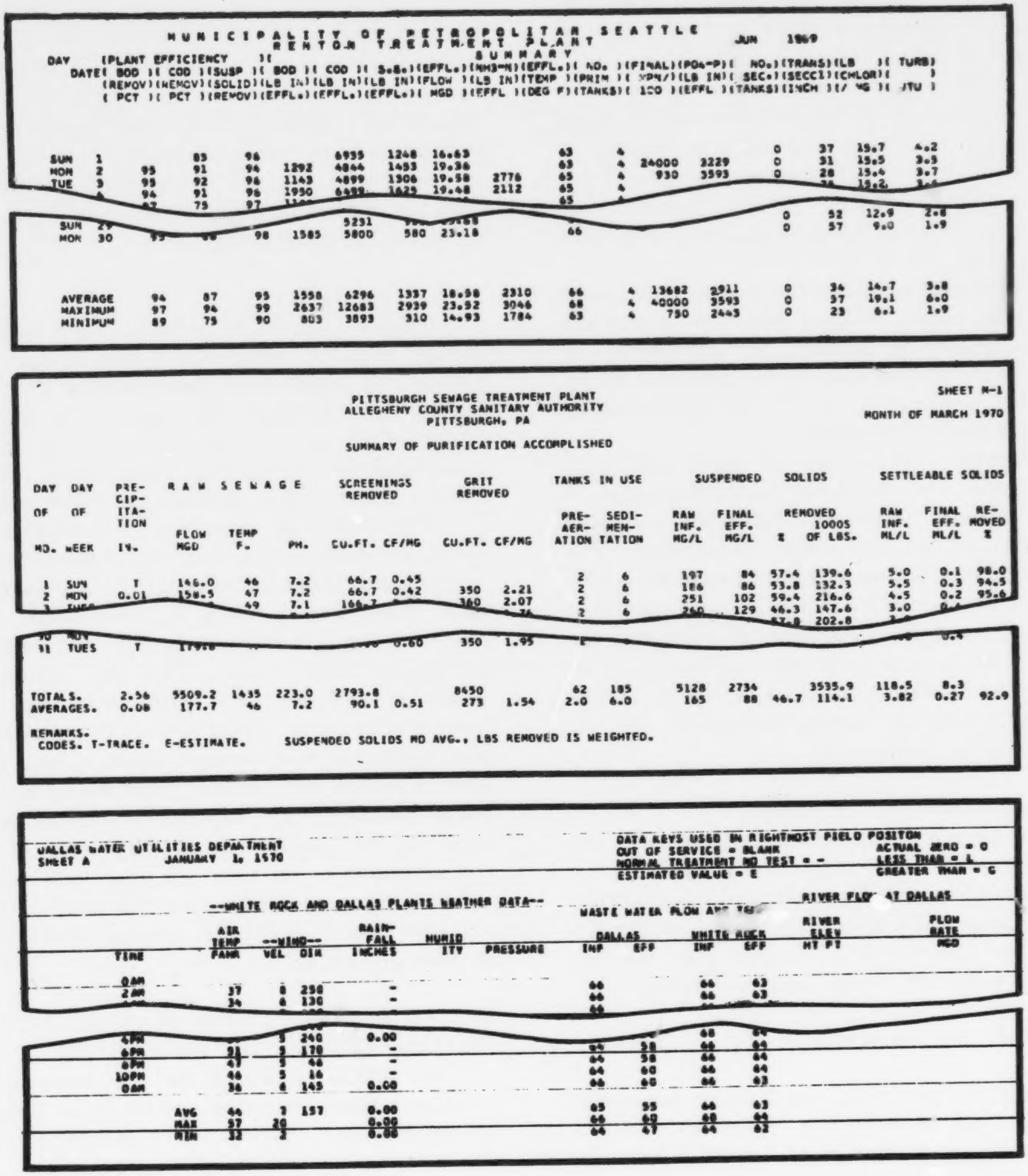
Program the checked-out *off-line* control models into the *on-line* (tied into equipment) system and retain those that continue to prove feasible. At this stage the digital computer is implemented into the dynamics of the plant operational system for both closed loop control and the processing of management information.

The following procedure is designed to gradually evolve a beneficial computer presence in the plant. While instrumentation is improved and supervisory control is centralized, the computer operations initially are non-critical, non-control applications. They are relatively simple, based upon current plant procedures and involve no real time closed loops. Computerizing plant information and maintenance records can serve a useful purpose for plant management, while personnel gain experience working in a computer environment. By the time programming is initiated for real time plant control, the computer presence and its operation will have become a familiar and dependable ally of plant processing.

DESIGN OF PLANT MANAGEMENT INFORMATION REPORTING SYSTEM

An initial approach to the wastewater treatment plant reporting system is to review thoroughly and update current procedures for direct compatibility with the needs of operational management and the requirements of computer implementation. The revisions should be implemented manually as soon as possible so that operational personnel can gain experience with the new requirements prior to computer implementation. This will facilitate verification of the automated version. Three excerpts from automated municipal wastewater plant reports are shown in Figure 12.

Consider, for example, a plant preparing to expand from primary to secondary treatment. Minimal primary reporting will be expanded to secondary where the amount of information to report as well as the justification for the computer will increase considerably. An early adjustment to computer reporting on the smaller



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              M U N I C I P A L I T Y   O F   M E T R O P O L I T A N   S E A T T L E
                           R E N T O N   T R E A T M E N T   P L A N T                 JUN    1969
DAY    (PLANT EFFICIENCY    )(                        S U M M A R Y
  DATE( BOD )( COD )(SUSP )( BOD )( COD )( S.S.)(EFFL.)(NH3-N)(EFFL.)( NO. )(FINAL)(PO4-P)(  NO.)(TRANS)(LB   )( TURB)
      (REMOV)(REMOV)(SOLID)(LB IN)(LB IN)(LB IN)(FLOW )(LB IN)(TEMP )(PRIM )( MPN/)(LB IN)( SEC.)(SECCI)(CHLOR)(     )
      ( PCT )( PCT )(REMOV)(EFFL.)(EFFL.)(EFFL.)( MGD )(EFFL )(DEG F)(TANKS)( 100 )(EFFL )(TANKS)(INCH )(/ MG )( JTU )


SUN   1            83     96           6935   1248   16.63            63      4                       0     37   15.7    4.2
MON   2     95     91     94    1292   4844   1453   19.36            63      4   24000   3229        0     31   15.5    3.5
TUE   3     95     92     96    1143   4899   1306   19.58    2776    65      4     930   3593        0     28   15.4    3.7
            94     91     96    1930          1625   19.48    2112    65      4                                    15.2
                   75     97                                          65

SUN  29                                5231                                                           0     52   12.9    2.8
MON  30                   98    1585   5800    580   23.18            66                              0     57    9.0    1.9


 AVERAGE    94     87     95    1558   6296   1337   18.58    2310    66      4   13682   2911        0     34   14.7    3.8
 MAXIMUM    97     94     99    2637  12683   2939   23.52    3046    68      4   40000   3593        0     37   19.1    6.0
 MINIMUM    89     75     90     803   3893    310   14.93    1784    63      4     750   2443        0     23    6.1    1.9
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                                         PITTSBURGH SEWAGE TREATMENT PLANT                                      SHEET M-1
                                       ALLEGHENY COUNTY SANITARY AUTHORITY
                                                PITTSBURGH, PA                                        MONTH OF MARCH 1970

                                       SUMMARY OF PURIFICATION ACCOMPLISHED

DAY  DAY   PRE-    R A W   S E W A G E     SCREENINGS      GRIT        TANKS IN USE      SUSPENDED    SOLIDS         SETTLEABLE SOLIDS
           CIP-                             REMOVED       REMOVED
OF   OF    ITA-                                                      PRE-   SEDI-     RAW    FINAL      REMOVED       RAW   FINAL  RE-
           TION                                                      AER-   MEN-      INF.   EFF.          1000S      INF.  EFF.   MOVED
                   FLOW   TEMP
NO. WEEK   IN.     MGD    F.     PH.   CU.FT. CF/MG  CU.FT. CF/MG    ATION  TATION    MG/L   MG/L    %  OF LBS.     ML/L  ML/L   %

 1  SUN     T     146.0   46     7.2    66.7  0.45                     2      6        197     84  57.4  139.6      5.0   0.1  98.0
 2  MON    0.01   158.5   47     7.2    66.7  0.42   350    2.21       2      6        186     86  53.8  132.3      5.5   0.3  94.5
                          49     7.1   166.7         360    2.07       2      6        251    102  59.4  216.6      4.5   0.2  95.6
                                                                       2      6        260    129  46.3  147.6      3.0
                                                                                                 57.8  202.8
31  TUES    T                                 0.60   350    1.95

TOTALS.    2.56  5509.2  1435   223.0  2793.8        8450             62    185       5128   2734        3535.9    118.5   8.3
AVERAGES.  0.08   177.7    46     7.2    90.1  0.51   273    1.54    2.0    6.0        165     88  46.7  114.1      3.82  0.27  92.9

REMARKS.
 CODES. T-TRACE.  E-ESTIMATE.     SUSPENDED SOLIDS MG AVG., LBS REMOVED IS WEIGHTED.
```

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                                                              DATA KEYS USED IN RIGHTMOST FIELD POSITON
DALLAS WATER UTILITIES DEPARTMENT                             OUT OF SERVICE = BLANK               ACTUAL ZERO = 0
SHEET A            JANUARY  1, 1970                           NORMAL TREATMENT NO TEST = -         LESS THAN = L
                                                              ESTIMATED VALUE = E                  GREATER THAN = G

                 --WHITE ROCK AND DALLAS PLANTS WEATHER DATA--                                   RIVER FLO  AT DALLAS
                                                                    WASTE WATER FLOW A
                      AIR               RAIN-                                                    RIVER          FLOW
                      TEMP   --WIND--     FALL   HUMID                 DALLAS     WHITE ROCK     ELEV           RATE
       TIME           FAHR   VEL  DIR   INCHES     ITY   PRESSURE    INF   EFF    INF   EFF     HT FT           MGD

        0AM                                                           66           66    63
        2AM            37     8   250      -                          66           66    63
                       34     6   130      -                          66

        4PM                   3   240     0.00                                     68
        6PM            31     5   170      -                          64    58     66    64
        8PM            47     5    46      -                          64    58     66    64
       10PM            46     5    16      -                          64    60     66    64
        0AM            36     6   145     0.00                        66    60     66    63

                 AVG   44     7   157     0.00                        65    55     66    63
                 MAX   57    20           0.00                        66    60     68    64
                 MIN   32     2           0.00                        64    47     64    62
```

Figure 12. Off-Line Computer Generated Excerpts from Wastewater Treatment Plant Reports

scale of primary treatment information can serve to familiarize personnel with computer applications and ease the expansion into secondary treatment reporting.

Furthermore, where plant automation is the eventual goal, the reporting system is the basis of operational information for studies of control by process computer. The reports become a comprehensive source of the entire scope of plant operational data. With both a store of conveniently tabulated data and the digital computer (as the tool) available, control guideline studies can be made without disturbing plant operation. An essential point previously mentioned is the necessity for each plant to base its approach to control on information gathered from its own operations.

DESIGN OF COMPUTERIZED EQUIPMENT MAINTENANCE FILE

A major computer application in a wastewater treatment plant is the design of a file for equipment maintenance records.

To continue with the example of a plant augmenting to secondary treatment, the preventive maintenance (PM) file is designed at an early stage for the primary treatment plant with its lower equipment complement. In this manner the small scale system can be more easily implemented and operated before the plant grows into secondary treatment. Once the file is in operation, new equipment data can be incorporated at any time.

The file itself should retain information on equipment identification, PM schedules, PM work monitor, and breakdown repairs. Some of the applications can be:

1. Scheduling and monitoring PM work,
2. Reporting on PM status,
3. Reminder of backlogged maintenance, and
4. Special studies on maintenance.

The basis for a PM file system should be implemented manually as soon as possible to accustom plant personnel to the concept, thereby facilitating eventual computer operation of the system.

COMPUTER PROGRAMS FOR REPORTING, PM FILES, AND OTHER OFF-LINE USES

The preparation of the computer programs is based upon the revised manual systems for plant reporting, preventive maintenance records, and other applications such as inventory control, payroll and accounting. The key to a successful computer program is a clear, well-delineated program design document which can serve simultaneously as:

1. The description of an operational system procedure understood by the user and meeting his needs and
2. A guide to the programmer as he writes instructions for the computer.

The transition toward computerized reporting extends through manual implementation of the reporting revisions and adoption of preventive maintenance record-keeping. Operating manually with the system will allow it to check itself out as a viable plant information exchange and communication procedure.

An inexpensive approach to gain experience and know-how in these early stages is to write the programs for a time-sharing, desk-side computer installation, such as is shown in Figure 13. The time-sharing approach ties the user into a modern, large-scale digital computer at modest rentals. Other facilities may be available, such as a municipal finance department or service bureau. They may be suitable and economic, but do not give the user immediate access to the computer.

The programs are written to implement the revised manual reporting procedures. Automating a functioning manual system should allow very little change in the basic information interfaces for users even as reports come to be generated by the computer.

Automated information systems are a reality and can be achieved. The success of the system requires a coordinated team effort, dedicated and committed to a completed product and backed by management.[35]

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[35] Sullivan, J.L. *What to do Until the Computer Comes (Part I and II).* Willing Water, AWWA. Dec. 15, 1969 and Dec. 31, 1969.

Figure 13. Using the Time-Sharing System

PLANT INSTRUMENTATION REVIEW AND UPGRADING

Simultaneous with the information and maintenance studies, a survey of all plant sensors and instrumentation should be performed. The emphasis should be on the replacement of laboratory procedures with on-line probes, solid state instrumentation and automated analytical procedures, suitable for continuous or sampled data monitoring and compatible with digital computer input. It should be noted that automation depends upon a sampled signal available from the controlled process. Upgrading the sensors improves plant process surveillance and the quality of plant reporting, and puts the plant into a more suitable status for implementation of closed loop control.

PRELIMINARY AUTOMATION STUDY AND COMPUTER SYSTEM SPECIFICATION

The initial phases of this plant automation approach introduce and make use of *off-line* computer work through a time-sharing system or other *off-line* computer arrangements. For plant control the process computer, which has the capability of tying directly into the plant system and doing *on-line* work, must be considered. The process computer is the tool to improve plant operations immediately, and more so in the future, as familiarity with its capabilities grows, and management acquires confidence in its application.

Because process computer hardware must be assembled and software *programmed* for its own special use, namely, the tie-in with the wastewater treatment plant, a study should be made prior to implementation to define its role. Unlike the time-sharing or other off-line digital computer into which any problem can be fed, the process computer is a dedicated, special purpose tool, programmed, in this case, to serve the improvement of wastewater treatment in its many complex facets of plant operation. To determine the computer functions, it is essential to study the plant by a team of plant management, wastewater treatment experts and computer application consultants. The preliminary automation study should review all plant operations and controls, both present and planned, to determine where the computer can be used to enhance the work of management and to improve treatment. The study should define the changes in operational procedure, the hardware and computer software requirements, the plant monitoring and control equipment, a schedule for implementation and budgetary costs.

The study results in a document to assist plant management in arriving at agreed upon procedures for continuation into the development of the system and specifications for the process computer.

The computer system specifications should establish the operational requirements of the process computer, its equipment complement, such as quantity of immediate access memory (core), auxiliary memory (disks, drum or magnetic tape), input-output and peripheral devices. The requirements for control displays, coordinated with plant management, can also be established. Consideration should be given to requirements for the plant controller console, displays and alarms.

IMPLEMENTING PLANT AUTOMATION

The previous steps in the progress toward automation are planned to include a sufficient elapse of time for smooth operation to develop between the off-line digital computer and daily plant procedures. Upgraded instrumentation should also be operating reliably. The goals to accomplish include:

1. Development of a reliable, digital computer presence at the plant,
2. Management recognition of the advantages of digital computer applications in wastewater treatment,
3. Management desire to increase implementation of the computer beyond *off-line* information processing into plant monitoring and operational control, and
4. Implementation of continuous monitoring instrumentation to allow the broadest range of computer monitoring and control.

A satisfactory experience with a rented computer will help ease phasing of the process computer into plant operations.

Implementation of plant automation will put the computer into the heart of plant control and operation, *on-line* a 24-hour day. The approach is to initiate automated plant operation primarily with data logging, monitoring for alarms and information reporting. System hardware can be checked out in conjunction with less critical plant functions, and prior to the initiation of closed loop control.

As the system is checked out and confidence grows, the more readily defined loops for operation control which may be direct conversions of manual control can be closed through the computer. The more complex control functions will continue to be studied via statistical and correlation analyses of the relevant collected and processed data until satisfactory control algorithms are evolved.

The initially implemented computer system is finally promoted to satisfactory operation of feasible closed loops, but not without overcoming great and frequently discouraging obstacles which should be anticipated. At this stage, study continues toward closing other loops as well as seeking improvement of those already operational. Further investigation should be directed toward developing optimization techniques to minimize cost, maximize contaminant removals, stabilize plant throughput, etc.

Seeking improvement is a never-ending cycle.

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SECTION 8
LOCAL INFLUENCES ON PLANT AUTOMATION

During preparation of this report certain situations were observed which related directly to automation of wastewater treatment plants and yet could not be categorized in the preceding sections. They do relate to local conditions however. The subjects considered are public concern over local water pollution, water quality as a resource and regionalization, all affecting operation of the local wastewater treatment plants. A discussion is also included on the unique Whittier Narrows Water Reclamation Plant at Los Angeles, California.

PUBLIC CONCERN

Where the local populace has become aroused over the problems of pollution, or where the receiving waters are heavily used for recreation, the wastewater plants are sensitive to criticism. If occurrences of polluted outfalls are aired via the news media, plant management will attempt to upgrade the effluent and prevent overflows. Seeking approaches to improve operations and to tighten controls, management will consider automation.

On the other hand, where there appears to be no problem and no local complaint about the effluent, there is a reluctance to change anything.

However, the state regulatory agencies and the Federal government are exerting pressure to upgrade effluents regardless of any apparent local indifference. As the pollution control agencies enforce their requirements through both funding assistance and fines, the plants will have to respond.

WATER QUALITY AS A RESOURCE

Concern is growing for the preservation of local bodies of water as resources to be protected from deterioration. Whether it is a stream, river, estuary, lake or ocean, the regulatory agencies are seeking to determine the quality status of the waters. There is widespread interest in monitoring, prediction of future conditions and pollution control measures.

Automation techniques suitable for continuous monitoring are available. When associated with a careful maintenance program, a network of water quality analyzers located at key points can yield reliable in-stream data. The information can be transmitted to a central computer to be logged, analyzed and reported with alarms for off-normal or emergency conditions.

Once the monitoring intelligence is converted to a set of properties of the body of water, quality status can be determined relative to what is desired. Where the status falls short, management of the water resource must be established to improve quality. As a consequence regulatory agencies impose restrictions upon the outfalls of municipal and industrial water pollution control plants.

Automation and digital computers can play an even larger role as further steps in sophistication are implemented. These include mathematical models of the diffusion and decay of pollutants and the variations in water quality variables through the body of water.

As a direct result of comprehensive water resources management, regulatory agencies have begun to stipulate specific upper limit quantities on effluent loadings to receiving waters. Constant BOD and suspended solids loadings in plant effluents are more difficult to maintain than percentage removals. Hence the use of a process control computer may be necessary to minimize plant process fluctuations and produce a more consistent effluent load.

REGIONAL WATER POLLUTION CONTROL SYSTEMS

One approach to improvement of local water resources is through a regional authority to manage water pollution control. Because of their geographic association in a natural drainage area, several communities, crossing political boundaries, can join to build a comprehensive treatment facility and a common collection system. The regional facility offers economic as well as practical benefits over separate, smaller

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plants.[36] Some of these are:

1. Scale of economy for capital and operating budgets,
2. Reduced cost per community,
3. More available revenue to attract higher calibre personnel,
4. Improved operation and control through greater available skills,
5. More efficient inventory,
6. More efficient overall regional planning for improvement and expansion, and
7. More effective compliance with regulatory agencies.

Furthermore, although the bypassing of raw sewage to the local receiving waters is far more detrimental from a large centralized plant, such a likelihood is greatly reduced. With proper contingency provisions, the large plant can divert flow among its units when one is out of service. On the other hand, a small plant generally has only one unit.

A large scale regional water pollution control plant with quality personnel is better equipped technically and economically to move into higher degrees of treatment and computer control. A large secondary treatment plant already has the skills, while small, local plants generally cannot afford them. Another incentive for the adoption of basin-wide pollution control systems is the Federal Government's promotion of such approaches to plant improvements in its grants program.[22]

Despite the advantages and Federal encouragement of the basin-wide approach to water pollution control, some words of caution are suggested. The central location of a treatment facility requires a comprehensive collection system of very long sewer lines. Effluents which would normally flow into local tributaries and augment the stream flow are carried away to be treated and disposed of at the central plant. Thus an area-wide depletion of stream flow is possible.

Simultaneously all the wastewater is focused to the regional plant and creates an inordinately large outfall at one location. The long lines transporting raw sewage to the central plant could be subject to septicity and odor problems.

It is generally felt that the advantages of regionalization outweigh the disadvantages. Nevertheless, each such plan should be carefully reviewed. With so much emphasis on centralized treatment systems, some studies should be undertaken to assess the real value of these plans on a geographic basis to arrive at either modifications to the plan or recommendations for the preferred geographic regions.

CONTROLLED PLANT INFLUENT

One of the requirements for optimum wastewater treatment is the attainment of a steady flow. Since raw wastewater flow is characteristically not steady, some influent control to allow constant flow would aid the cause of improved treatment and automation. A basin for raw wastewater storage prior to plant entry could prove useful for equalizing flow, especially during storms.

The Whittier Narrows Water Reclamation Plant, shown in Figure 14, uses another approach. The plant itself is superimposed on the existing sewerage system. A steady rate of 15 mgd is pumped from a large trunk sewer passing through the plant site. The large sewer carries 50 mgd of principally domestic sewage. Inlet pumps from Whittier Narrows are set for a constant rate and "maintain a steady hydraulic loading 24 hours a day".[37]

All sewage solids upon separation are returned to the trunk sewer for transport downstream to another plant. Water reclamation is executed by channeling effluent to spreading basins for percolation into the ground and subsequent use in water supply. Hence the favorable flows situation extends to steady plant effluents as well as influent.

Primarily an activated sludge treatment plant with well controlled steady flows, the Whittier Narrows plant is ideally amenable to closed loop control and makes use of a high degree of instrumentation. Variable speed

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[36] Classen, N.W., B.G. Scalf, and J.B. Copeland Jr. *Economics of Regional Sewerage Systems.* Public Works. April 1970.

[22] *Federal Register. op. cit.*

[37] Parkhurst, J.D. and W.E. Garrison. *Whittier Narrows Water Reclamation Plant – Two Years of Operation.* Civil Engineering. Sept., 1964.

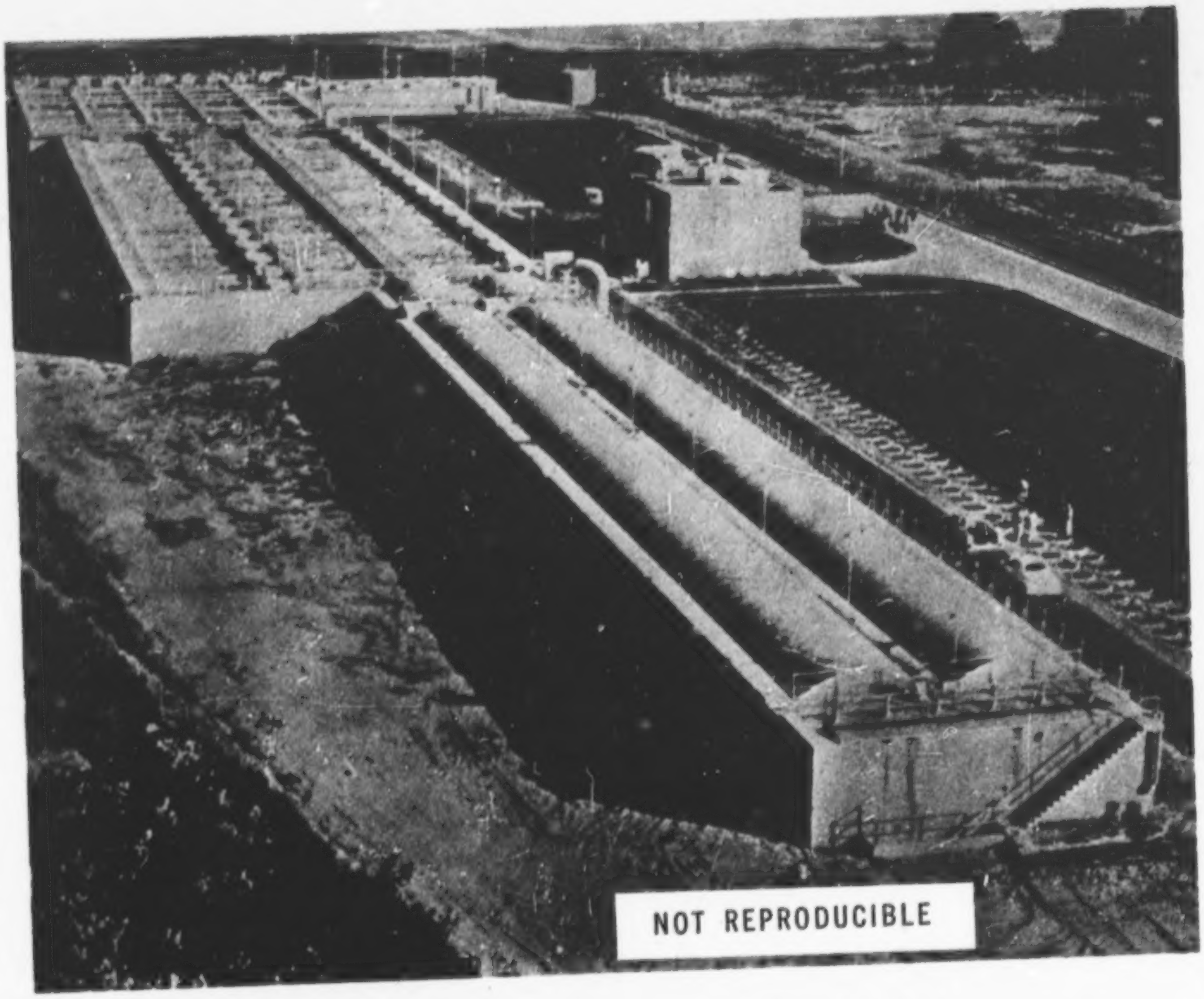

Figure 14. Whittier Narrows Water Reclamation Plant

wastewater pumps automatically maintain flow to the primary tank. In the final clarifier, the sludge blanket level is continuously sensed by a Hach falling-stream turbidity meter which determines the rate of sludge withdrawal for return to aeration. The blowers supplying air operate virtually unattended. Chlorine residual is continuously monitored, and chlorine automatically fed to the effluent. These controls permit minimal use of manpower, two operators and one laboratory technician on a six day, 48-hour week.

The Whittier Narrows plant is a unique and advantageous system of operating a wastewater treatment plant where flow can be regulated to meet plant requirements. Its success has resulted in future planning in Los Angeles County for other such plants to be superimposed on existing sewerage networks, and can serve as a model for other communities.

SECTION 9
ADVANCED RESEARCH ON CONTROL SYSTEMS

The need for sensing for mounting operations which are primarily organic rather than chemical in nature was recognized throughout the project. Information concerning rapid BOD determination and control of the activated sludge process was obtained and is presented here to give an indication of how control may be achieved.

RAPID BOD DETERMINATION

The BOD test, which defines the pollutional strength of wastewater, is one of the most important variables in plant monitoring and control. However, the industry standard for BOD is based upon a five-day incubation period to generate a value. This eliminates the possibility of using BOD for real-time operational control. There have been studies, notably by R.A. Arthur of Rose Polytechnic Institute and R.S. Ingols of Georgia Institute of Technology to determine BOD in much shorter time.

Professor Arthur makes use of an automatic respirometer to determine the oxygen uptake of bacteria cultures.[38] The instrument manometically senses the reduction in partial pressure of the oxygen as it is consumed by the wastewater sample, converts it to an electrical signal and continuously records the value. The result is a graph of oxygen consumption versus time. The immediate advantages are an elimination of tedious data taking and curve plotting.

A series of oxygen uptake curves generated by the system were investigated to determine whether they could serve to predict the five-day BOD from a much shorter period of plotted data.[39] The comparison with a standard five-day BOD dilution test of a series of oxygen uptakes through a four-hour period yielded an average error of 21.3 percent. A similar seven-hour period test yielded an average error of 15.8 percent. These errors are not considered large when it is recalled that the five-day BOD is reported to have an accuracy of plus or minus 20 percent.

Further study involved the fitting of quadratic functions to the uptake data of 48 plots. For each run the standard deviation of the computed curve from the actual uptake curve was computed yielding the following table of results:

Hours of Demand Curve	Percent Deviation From Quadratic Fit
7	2.1
4	5.0
3	7.5

The reference concludes that the five-day BOD can be predicted with reasonable accuracy using four hours of uptake data from the automatic respirometer.

Through continued research Professor Arthur has evolved an automatic respirometer capable of yielding an oxygen demand measurement within fifteen to thirty minutes. Although the reading is not the standard BOD_5 Professor Arthur claims it is suitable for monitoring and control.

Professor Ingols performs a repetitive short term BOD Test[40] utilizing a dissolved oxygen electrode unit. A measured sample is aerated for a nine minute period in a chamber while the DO reduction is recorded. The device can generate information every ten minutes on the rate of oxygen depletion at the selected sampling point. The author states that the dissolved oxygen during each period is recorded, and the records "compared to indicate what BOD load exists." Analytical relationships are not discussed.

The purpose of the "repetitive, short term BOD test" is to generate information for

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[38] Arthur, R.M., *An Automated BOD Respirometer*, Proceeding of the Nineteenth Industrial Waste Conference, May 5, 6, 7, 1964, Purdue University

[39] Arthur, R.M. and Hursta, W.N., *Short Term BOD Using the Automatic Respirometer*, Proceedings of the 23rd Industrial Waste Conference, May 7, 8, 9, 1968, Purdue University

[40] Ingols, R.S., *Short Term BOD*, Water & Sewage Works, April 1968

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optimum monitoring and control of an activated sludge plant. Automatic sampling, recording and analysis is clearly stated as necessary to provide the operator with frequent and sufficient current information to promote better decisions and to reduce periods of uneconomic or inefficient operations.

Recent improvements in the short term BOD detector permit a one minute detection time, allowing for a permissable minimum period of five minutes between readings. The oxygen uptake is computed by an automatic subtraction of initial DO from final DO.

CONTROL OF THE ACTIVATED SLUDGE PROCESS

P. Brouzes of Omnium d'assainissement, France, has installed control systems for the activated sludge process which can control aeration and excess sludge removal continuously according to the pollution load.[41] At least twenty of these systems are currently operational in France at a cost of about $20,000 to install. Practically automatic operation of the plant is assured with controls varying in complexity from the simple regulator to the analog computer. The instantaneous pollution load and specified operating conditions define the automatic removal of excess sludge. Maintaining a constant dissolved oxygen concentration determines the air input.

The method avoids "empirical" control practices of constant air input and periodic sludge removals based on volume or weight. The empirical approaches lead to uneconomical safety margins and uncontrolled variations in the growth rate of microorganism cultures.

Inherent in the Brouzes process is intelligence of the growth rate of an activated sludge culture. The author demonstrates through a mathematical derivation (in the aforementioned reference) that the growth rate can be defined, instantaneously detected, controlled and regulated.

The derivations relate the energy required for oxygenation to the pollution load. Since the excess sludge removal is also related to the pollution load, the power consumed by the blowers can be used to control the removal of waste activated sludge.

The simplicity and advantages of economy in the Brouzes method offer more promise than other methods dependent upon online measurement of organics.

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[41] Brouzes, P., *Automated Activated Sludge Plants with Respiratory Metabolism Control,* Advances in Water Pollution Research, Proceedings of the 4th International Conference, Prague, 1969

SECTION 10
RECOMMENDED RESEARCH

As a consequence of the work performed on the study *Feasibility of Computer Control of Wastewater Treatment*, recommendations for continued research have evolved. These are listed and described. For each project, the need, objective, and time required are stated.

DEVELOPMENT OF A SUSPENDED SOLIDS PROBE

Introduction

A probe-type instrument could be developed to measure the concentrations and densities of various size particles in water, using an electrolytic (Coulter-type) counter. These counters are commercially available, batch-measuring instruments which size and count particles in an aqueous medium, with a sensitivity of one micron or less.

By developing: 1) a continuous-flow sampling probe and 2) automatic data processing of the output pulses, the counter could be used to give a continuous measurement of the number of particles in any desired size range. Furthermore the size range could be adjusted electronically without modifying the probe.

Objectives

The objectives of the proposed program are: 1) to evaluate several flow-through sampling concepts which have been developed, 2) to develop the electronic logic circuitry to pulse-height analyze the resulting pulses and 3) to categorize and enumerate them according to particle size.

Time Estimate

The time will require a fifteen-month effort.

DEVELOPMENT OF AN INSTRUMENT FOR RAPID DETERMINATION OF BIOCHEMICAL OXYGEN DEMAND

Introduction

It may be possible to develop a near real-time instrument to measure oxygen demand which would correlate with the 5 day BOD test.

Because the rate of oxidation of a substrate is a function of its concentration in most enzyme reactions, controlled constant addition of oxygen should result in maintaining the oxygen tension of an oxidizing wastewater sample at a level which is dependent on the rate of oxidation and therefore on the concentration of oxidizable materials. The resulting O_2 tension should therefore be a measure of short term BOD.

Objectives

The objectives of the research include the design and verification of a device employing a controlled oxygen addition method of BOD analysis. Design parameters must be established for O_2 diffusion rate, O_2 demand rate, and O_2 tension which will determine pumping rate and coil dimensions. A laboratory breadboard must be designed, constructed, and tested and the results compared to Standard Methods for BOD analysis, using a variety of sample sources.

The correlation between the proposed short term BOD and the standard 5 day BOD must be evaluated to determine quantitative relationships. These relationships will depend on supplementary characterization of the sample by other rapid chemical analysis means.

Time Estimate

It is anticipated that this program will require a two-year schedule.

DEVELOPMENT OF AN INSTRUMENT FOR RAPID FECAL COLIFORM COUNTING

Introduction

A technique is under development at General Electric by which the 24-48 hour coliform test can be performed in approximately 4 hours. This is based upon metabolizing a labeled nutrient to produce radioactively labeled metabolic products. These products can be conclusively identified and measured long before measurable colonies have formed. The heart of this method is the GE silicon avalanche diode which can detect very low concentrations of the radioactive metabolic effluents.

Objectives

In the proposed study, this technique is to be extended to very short culture periods, providing near real-time analysis of coliform counts. Microorganisms in a water sample are to be concentrated on the membrane filter and exposed to Endo broth MF enriched with ^{14}C-lactose. $^{14}CO_2$ evolved by lactose fermenters will be captured by a getter and the radiation monitored by a GE avalanche detector. Read-out is contemplated on a digital printer or strip chart recorder.

The feasibility study will correlate the level of radiation monitored with the actual number of viable fecal coliforms in the original sample.

Time Estimate

The feasibility study for near real-time fecal coliform counting will require a fifteen-month program.

An instrument to perform this analysis might be developed by adapting the liquid-liquid extractor of the General Electric phenol analyzer to separate the mercury ions from interfering cations.

ANALYSES AND PROCEDURES FOR COMPUTER CONTROL OF WASTEWATER TREATMENT PROCESSES

Introduction

With nationwide concern for upgrading secondary treatment and seeking higher quality effluents via tertiary treatment, computer control can help. There is a need for analyses of wastewater treatment processes with regard to computer control, since most current studies and computer simulations examine optimization of process design.

Before consideration can be given to the computer, management must thoroughly analyze plant operational control, process by process. This can be done in a general way among different plants to accommodate the most common treatment phases as well as the new advanced types.

One of the major considerations in computer control of wastewater treatment is the list of tasks to be assigned to the process control computer. For each treatment facility to be associated with automatic monitoring and control, the information entering the computer, the logic and computations relevant to reporting and control, and the information leaving the computer must be defined. The logic and computation procedures are written in flow chart form to serve two documentation purposes:

1. A record of the process requirements for monitoring and control identifiable to plant management, and
2. Guidelines for computer programming.

The document will also serve to determine hardware and software requirements for plant automation.

Objectives

The objectives of the proposed project are to develop and document the computer-stored procedures for continuous monitoring and control of wastewater treatment. The steps are to be prepared for existing wastewater treatment plants encompassing processes through tertiary and advanced treatment, and will reflect the most advanced thinking and good practices of engineering management.

Time Estimate

To perform an analysis and to develop flow charts for monitoring and control of wastewater treatment processes will require a fifteen-month schedule.

USERS' EXPERIENCE INSTRUMENTATION STUDY FOR WASTEWATER TREATMENT PROCESSES

Introduction

Among the major impediments to the achievement of full computer control of wastewater treatment is the lack of satisfactory sensors for continuous process monitoring. Some sensors do not cover a wide enough range; others are unreliable; and for some wastewater treatment processes, no continuous monitoring instrumentation is available. Thus, there is a need for a comprehensive field study of *users' experiences* with installed and operating on-line instrumentation to learn their recommendations for improvements and to define bases for new instrumentation. Such a study would provide a base-line and direction from which manufacturers could proceed to fulfill this need.

Background

As a result of the survey relating to *Computer Control of Wastewater Treatment* (SECTION 4) and recent contacts with managers of treatment facilities, it has become apparent that there are fundamental gaps in continuous monitoring technology for wastewater treatment. It is still impossible to react quickly enough to variations in plant influent, and in certain treatment processes, to minimize undesirable effluent characteristics. It is, therefore, equally impossible to implement continuous computer control on those variables. Inefficiencies and attendant uneconomical plant operations still occur, and the quality of the effluent may not always meet or exceed established criteria.

While industry is continuing to improve monitoring devices with better packaging and solid state circuitry, plant management still finds them requiring too much attention for satisfactory operation.

Objectives

The objectives of this study will be to determine, on a nationwide basis, for each process within primary, secondary, and tertiary wastewater treatment plants:

1. The effectiveness of installed and operating on-line sensors,
2. The effectiveness of installed and operating automated analysis instrumentation,
3. Present needs for improvement in existing instrumentation, and
4. Present needs for new instrumentation.

The effectiveness of installed and operating instrumentation will be gauged by considering such characteristics as its performance (e.g., range, accuracy, response time, etc.) with relation to the variable being measured; costs (procurement, installation, operation and maintenance), and simplicity of connection to the process. Present and future needs must not only be expressed in general terms, but must be quantified into specifications which can be used to develop the needed instrumentation.

Time Estimate

To perform the survey of users' experience in wastewater treatment instrumentation will require a fifteen-month schedule.

AUGMENTED INSTRUMENT SURVEY

Proposed Future Work on the Instrument Survey

The usefulnes and value of the instrument survey included in this document (Section 13) can be increased by: 1)expanding the information content, 2)enlisting the aid of equipment manufacturers, 3)building a computerized data bank, and 4)making the information readily available.

Expand Information Content

The introductory nature of the information contained in the present survey necessarily limits the amount of useful data which can be presented. To help a user more effectively narrow down his search for candidate instruments, it is recommended that the survey be expanded. This would provide room for such potentially useful information as: cost, power requirements, maintenance requirements (recalibration, duration for unattended operation – some analyzers require reagents to be replenished and/or their sensors to be cleaned); optimal equipment for readout, recording, transmission and telemetry; more detail on ranges of measurement; information on specific applications and limitations; and so on.

Enlist Aid of Equipment Manufacturers

To facilitate the gathering of information and to ensure that all applicable equipment offered by a manufacturer is included in the survey, it is proposed that the manufacturers themselves generate the information. This would eliminate the need to glean information from catalogs, and would ensure that all information is current. By going directly to the manufacturers, information could also be requested which might not normally be included in their catalogs (e.g., price, maintenance requirements, specific applications or limitations).

Because information of this type is subject to frequent changes, especially pricing, a procedure for periodic updating would be provided. The ultimate situation would be one in which the manufacturers would keep the survey alive, once it gained acceptance, by deeming it essential to their product's visibility.

Build a Computerized Data Bank

As the survey grows in size, it would eventually become more efficient to build a computerized data bank to eliminate the handling of unwieldly card decks. This would also provide a degree of flexibility that would be difficult to achieve with the present system.

When generating the software for the data bank, special attention would be given to facilitating its use by personnel without programming skills. The software can be designed to lead the user through all of the operating steps in response to his initial typing in of key request words. Provisions can be made for detecting input errors and allowing the user to see changes before they are finalized (especially important when deleting data).

Make the Information Readily Available

The success of the survey will ultimately depend upon its acceptance as a useful source of accurate data for wastewater instrumentation and equipment. In order to promote and encourage its use, the survey should be published in technical journals and trade magazines as well as a separate technical paper. Publishers should be informed of the potential value that a survey of this type could have, that is, its periodic publication as a special feature of a journal would not only add to the value of the sponsoring publication, but could also boost its circulation.

Time Estimate

To build the data bank and its associated computer program for information on available continuous monitoring instrumentation would require a fifteen-month schedule to completion

COMPUTER IMPLEMENTATION FOR MONITORING AND CONTROL OF A WASTEWATER TREATMENT PLANT

Introduction

The study, *Computer Control of Wastewater Treatment*, has evolved a documented *Guidelines for Computer Implementation*. It is recommended that they be put to practice. There are sufficient workable applications to encourage an approach toward automation, despite the lack of both treatment knowledge and adequate instrumentation in some areas. To achieve a computer controlled wastewater treatment plant is the ultimate goal of this study.

The requirements of a project of this magnitude can only be briefly outlined in this document. The text contains two sections suitable as a guide to computer applications. These are:

- SECTION 6 Guidelines for Computer Implementation
- SECTION 7 Measured Steps Toward Plant Automation

Objective

To automate a medium sized (10 to 50 mgd) secondary wastewater treatment plant by process computer implementation.

FEASIBILITY STUDY FOR RAPID MERCURY ANALYSIS

Introduction

The recent public concern with mercury pollution indicates that analysis for mercury content, however inconvenient, will increasingly be required. Neutron activation analysis is beyond the resources of most laboratories. In order to achieve the sensitivity required, atomic absorption spectroscopy requires sample concentration and liquid-liquid extraction. Neither of these methods are readily adaptable to field laboratory operations. There is a definite need for a low-cost method for simplifying and/or automating the assay technique.

An instrument to perform this analysis could be developed by adapting the liquid-liquid extractor of the General Electric phenol analyzer to separate the mercury ions from interfering cations.

Objectives

The objective of this program is to ascertain and optimize the technical details involved in adapting the semi-automatic liquid-liquid extraction capabilities of the GE-developed phenol analyzer to colorimetric mercury determination. Work could be performed to determine the nature of the necessary modifications, and then to obtain the optimal conditions, reagent concentrations, reaction duration and procedure.

Time Estimate

This feasibility study will require a fifteen-month effort.

DEVELOPMENT OF AN ON-LINE PHENOL SENSOR PROBE

Introduction

A probe-type sensor for phenol and phenolic derivates could be developed, based on the General Electric phenol analyzer. This batch-type analyzer uses liquid-liquid extraction to separate phenolics from a wide variety of interfering substances. The extracted phenolics are reacted by standard methods to produce a characteristic absorption line at 457 mμ, and their concentration is measured spectrophotometrically. The current General Electric analyzer will detect phenolics in water with a sensitivity of 0.1 to 1.0 part per billion.

A probe-type sensor could be developed by 1) partitioning the phenolics with a selective membrane rather than a liquid-liquid extractor and 2) measuring their concentration directly by fluorescent spectroscopy, thereby eliminating the colorimetric reactions and spectrophotometry.

Objectives

The objectives of the proposed research are: 1) to evaluate the partition coefficients for various membrane materials, some of which have been developed for specific-ion probes, 2) to measure the fluorescent efficiency of the partitioned phenolics, and 3) to design a prototype sensor for continuously measuring phenolics in water.

Time Estimate

The feasibility evaluation and prototype fabrication of a continuous probe-type phenol analyzer will require an eighteen-month schedule.

DEVELOPMENT OF AN ON-LINE TRACE OIL MONITOR INSTRUMENT

Introduction

There is an urgent need for an instrument to make real-time in-situ measurements of trace oil in water, including thin films and dispersed and/or emulsified oil. The present method is to take a sample to a laboratory, concentrate the oils and then measure them by solubility tests, by chemical reactions, or by IR absorption or spectroscopy.

A concept has been evolved for an instrument which would continuously draw a sample of the oil/water, extract and concentrate the oils, and measure them by IR absorption at a critical wavelength.

A continuously sampling, real-time technique capable of making quantitative measurements in the low ppm range must perform two functions: It must first concentrate the oil, and second, it must analyze the concentrated sample. The proposed method is to:

1. Concentrate the oils by countercurrent solvent extraction and

2. Measure them by IR transmission spectroscopy.

This lends itself to a continuous monitor which draws a sample through an extractor into the flow-through absorption cell. The key to this technique is the countercurrent liquid-liquid extractor developed at the General Electric Company and which can partition and concentrate the oils in real-time.

Objectives

The objectives are to investigate the extraction efficiencies and IR transmission windows of various solvents, provide a laboratory feasibility demonstration of the concept, and establish an engineering prototype design. Test results can be presented in terms of IR spectrometer absorption curves, nephelometric scattering, and photographs of the state of emulsification of the oil used in each test.

Time Estimate

The task will require a fifteen-month effort

SECTION 11
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SECTION 12
GLOSSARY

ACTIVATED CARBON. Carbon particles usually obtained by carbonization of cellulosic material in the absence of air and possesing a high absorptive capacity.

ABSORPTION. The taking up or into a solid, gas, liquid or dissolved material.

ADSORPTION. The adherence of a gas, liquid, or dissolved material on the surface of a solid.

AEROBIC. Requiring the presence of free elemental oxygen.

ALGORITHM. A fixed step-by-step procedure for accomplishing a given result.

ANAEROBIC. Requiring the absence of air or free elemental oxygen.

ANION. A negatively charged ion in an electrolyte solution, attracted to the anode under the influence of electric potential.

BREAKTHROUGH. The point where an ion exchange column begins to lose its ion removal capability.

BUFFERING. The use of certain combinations of chemicals to stabilize the pH values of solutions.

CATION. The ion in an electrolyte which carries the positive charge and which migrates toward the cathode under the influence of a potential difference.

CHLORINE DEMAND. The difference between the amount of chlorine added to water or wastewater and the amount of residual chlorine remaining at the end of a specified contact period. The demand for any given water varies with the amount of chlorine applied, time of contact, and temperature.

CLARIFICATION. Any process or combination of processes the primary purpose of which is to reduce the concentration of suspended matter in a liquid.

CLARIFIER. A unit the primary purpose of which is to secure clarification. Usually applied to sedimentation tanks or basins.

COMPUTER MEMORY. A device for storing information and instructions in a digital computer. Examples of memory include magnetic core, disks, drums, and tape.

DIGESTERS. Tanks in which sludge is placed to permit digestion to occur. Also called sludge digestion tank.

EMPIRICAL FORMULA. A formula developed to describe a relationship on the basis of experience and data gathered from actual operations.

FEEDBACK (CONTROL). An automatic furnishing of data concerning the output of a machine to an automatic control device so that errors may be corrected.

FILTRATE. The liquid which has passed through a filter.

FLOW CHART. An orderly representation of a process. A graphic illustration in which activities are defined and their interrelationships are illustrated.

INFILTRATION. The discharge of groundwater into sewers, through defects in pipelines, joints, manholes or other sewer structures.

INFLOW. The discharge of any kind of water into sewer lines from such sources as roof leaders, cellar and yard area drains, foundation drains, commercial and industrial so-called *clean water* discharges, drain from springs and swampy areas, etc.

INPUT-OUTPUT DEVICES. Devices for entering and extracting information from computers: card readers, card punch, typers, printers, cathode ray tubes, etc.

INTERMEDIATE TREATMENT. The removal of a high percentage of suspended solids and a substantial percentage of coloidal matter, but little dissolved matter.

KJELDAHL. The Kjeldahl method employs sulfuric acid as the oxidizing agent to free nitrogen as ammonia from organic compounds in the standard nitrogen testing procedure.

MATHEMATICAL MODEL. The mathematical representation of a process or operation for which solutions can be obtained for a set of input variables.

MIXED LIQUOR. A mixture of activated sludge and organic matter undergoing activated sludge treatment in the aeration tank.

MODELING. A simulation technique for the analysis of operations and systems.

NITRIFACATION. The conversion of nitrogenous matter into nitrates by bacteria.

OFF-LINE COMPUTER. A free standing digital computer not tied into an industrial process.

ON-LINE. Tied into a process and operating continuously.

ON-LINE COMPUTER. A computer which is integrated into the dynamics of a process; a process control computer.

OUTFALL. 1) The point, location, or structure where wastewater or drainage discharges from a sewer, drain, or other conduit. 2) The conduit leading to the ultimate disposal area.

PARSHALL FLUME. A calibrated device developed by Parshall for measuring the flow of liquid in an open circuit.

PATHOGENIC. A description of organisms which may cause disease in the host organism by their parasitic growth.

PERCOLATION. The movement or flow of water through the interstices or the pores of a soil or other porous medium.

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PERIPHERAL DEVICES. Input/output equipment used to make hard copies or to read in data from hard copies (typer, punch, tape reader, line printer, cathode ray tube, plotter).

PRIMARY SETTLER. The first settling tank for the removal of settleable solids through which wastewater is passed in a treatment works.

PROCESS COMPUTER. A digital computer having direct communication capability with an industrial process for data sampling and equipment control.

REGENERATION. The process of restoring an ion exchange material to the state employed for adsorption (in ion exchange).

REGRESSION ANALYSIS. The analysis of the association among several variables.

SCANNER, REMOTE. A device which will, upon command, connect a specified sensor to measuring equipment and cause the generation of a signal suitable for input to a computer.

SIMULATION. Operating a logical-mathematical representation of a concept, system or operation.

SLUDGE. 1) The accumulated solids separated from liquids, such as water or wastewater, during processing, or deposits on bottoms of streams or other bodies of water. 2) The precipitate resulting from chemical treatment, coagulation, or sedimentation of water or wastewater.

SLUDGE BLANKET. Accumulation of sludge hydrodynamically suspended within an enclosed body of water or wastewater.

STEADY-STATE PROCESS. A process which has reached a relatively stable operation, no longer changing with time.

STREAM VECTOR. An identification of the variables comprising wastewater characteristics which are changed by treatment processes.

STREAMING POTENTIAL – The difference of electrical potential between a porous diaphram, or other permeable solid, and a liquid which is passing through it. This arises from an imposed movement of solvent through capilaries.

SUBSTRATE. 1) The substances used by organisms in liquid suspension. 2) The liquor in which activated sludge or other matter is kept in suspension.

SUPERNATANT. The liquid standing above a sediment or precipitate.

SUSPENDED SOLIDS. 1) Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering. 2) The quantity of material removed from wastewater in a laboratory test, as prescribed in *Standard Methods for the Examination of Water and Wastewater* and referred to as nonfilterable residue.

TELEMETRY. The system of measuring, transmitting and receiving apparatus for indicating, recording or integrating at a distance, by electrical translating means, the value of a quantity.

TIME-SHARING. The simultaneous use of a computer system from multiple terminals; provides economics through cost-sharing.

TOTAL SOLIDS. The sum of dissolved and undissolved constituents in water or wastewater, usually stated in milligrams per liter.

TOXIC. Usually referred to in this document as fatal to the aerobic and anaerobic organisms.

TRICKLING FILTER. A filter consisting of an artificial bed of coarse material, such as broken stone, clinkers, slate, slats, brush, or plastic materials, over which wastewater is distributed or applied in drops, films, or spray from troughs, drippers, moving distributors, or fixed nozzles, and through which it trickles to the underdrains, giving opportunity for the formation of zoogleal slimes which clarify and oxidize the wastewater.

VARIABLE. A quantity to which an unlimited number of values can be assigned in an investigation.

ZETA POTENTIAL. An electrical charge at the boundary between particles and the suspending medium that is related to repelling forces between floccules.

SECTION 13

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SECTION 14 – APPENDIX
CONTINUOUS MONITORING INSTRUMENTATION SURVEY

METHOD

The survey has compiled a list of automatic monitoring instrumentation on the market for continuous monitoring of wastewater treatment processes and receiving waters.

The survey tabulated: an instrument listing, manufacturers names and addresses, abbreviations, symbols and a list of those variables which are usually measured for monitoring a specific treatment process. (Table 4). Excluded from this survey are portable and laboratory instruments, and those requiring manual samples.

The instrument listing has been subdivided according to classification, i.e., water quality, flow, level, etc. This listing and the one of measurements vs. wastewater treatment processes can guide the user in instrument selections.

Data were obtained from manufacturers' catalogs and from those who advertise in trade journals, such as: *Public Works* magazine, *Water and Wastes Digest, Water and Sewage Works, Pollution Equipment News, and the American City.*

DESCRIPTION OF SURVEY DATA AMONG THE LISTINGS

A format was selected which utilizes two standard 80-column computer cards for each instrument description. The first card contains information about the instrument itself. The second card contains the manufacturer and some additional information. A description of each field heading follows (Table 5):

1. *Variable.* This describes what the instrument measures. Where H2O QUAL indicates that there are many possible measurements, the COMMENTS field should be referred to for the specific variables measured.

2. *Instrument.* Manufacturer's name for his instrument. In many instances, a range of model numbers is indicated, while in other cases, only the name of the instrument line has been given (e.g., MAGNETIC FLOWMETERS and TURBINE FLOWMETERS have numerous models which depend upon pipe size).

3. *Ranges.* Where an integer or M (for multiple) appears within the specified range limits, or that the number of ranges can be achieved by virtue of the numerous models available, each of which may have one or more ranges.

4. *Range Limits.* This indicates the extreme ranges of measurement.

5. *Method.* The method or basic principle used to achieve the measurement is cited. For water quality monitor packages, this may be blank because of the numerous methods used to measure multiple parameters.

6. *Outputs.* Standard and optional output signals are listed.

7. *Manufacturer.* The name may be shortened due to lack of field space. However, the complete name is given under the list of MANUFACTURERS NAMES and ADDRESSES.

8. *Comments, Other Outputs, Water Quality Variables.* This field is used to provide other useful information. For water quality instruments, this field will contain specific measurements available.

The symbols and abbreviations for Table 5 are given in Table 6, and the manufacturers' addresses are listed in Table 8. Table 7 contains a list of thirteen manufacturers of automatic sampling equipment for one or more variables.

RESULTS AND USES

A user of the compilation will have at his fingertips, virtually all potentially useful continuous monitoring instruments and their manufacturers. Inquiries to a manufacturer will be more direct and the time shortened, since a caller will already have basic details about specific instruments.

TABLE 4. MEASUREMENTS FOR WASTEWATER TREATMENT PROCESSES

	Measurements																		
Process	pH	Temp	ORP	DO	BOD COD TOD	PO_4	Toxic metals	NO	CL	Alkal-inity	Susp.	NH_5	KJEL-DAHL N	Liquid flow	Level	Gas volume	% CO_2	% Methane	Air flow
Influent flow (at plant)	X	X	X	X	X	X	X	X		X	X		X	X					
Bar screen														X	X				
Raw wastewater pump														X	X				
Grit channel	X	X	X		X	X	X				X		X						
Primary sedimentation	X	X	X	X	X	X					X	X	X	X	Sludge level				
Trickling filter	X	X			X		X							X					
Aeration tanks	X	X	X	X	X	X		X			X	X	X	X					X
Secondary clarifiers		X	X		X			X			X	X	X	X	Sludge level				
Oxidation pond				X															
Chlorine contact chamber			X		X	X		X	X		X	X	X						
Return sludge			X	X							X			X					
Primary sludge			X											X					
Waste activated sludge			X											X					
Sludge thickening (gravity)					X						X			X					
Sludge thickening (floatation)					X						X			X					
Sludge digestion	X	X	X							X				X		X	X	X	
Sludge dewatering														X					
Elutriation					X	X				X	X	X		X	Sludge level				
Pipeline to sea											X			X					
Incineration		X																	
Receiving water	X	X	X	X	X	X	X	X	X	X		X	X						

TABLE 5

AUTOMATIC MONITORING INSTRUMENTATION FOR WASTEWATER TREATMENT PROCESSES (1 of 2)

Variable	Instrument	Range	Range Limits	Method	Outputs	Manufacturer	Comments, other Outputs, Water Quality Variables
FLOW MEASURING INSTRUMENTS							
Flow	Series 600 magnetic mtrs					American Meter	Brochure not received
Flow	Flumes, weirs, nozzles	M	.1-30 Mgd	Primary	V	Badger Meter Mfg	Uses Badger ML-MN trmtr to sense level (Flow)
Flow	Magnetic resonance meter	1	5-50 Gpm	Mag res	V, A, dig	Badger Meter Mfg	Totalizer avail. Special fluid properties required
Flow	Universal venturi	M	To 16K Gpm	Primary	Press	Bif	Pressure transmitter required. Available from Bif
Flow	Brooks-mag flowmeter	M	100K Gpm	Emf	V, A, Tm, R, rcdr	Brooks Instrument	Totalizer avail. Pneumatic output available
Flow	Fullview, armet rotameters	M	1-2.5K Gpm	Rotameter	V, press, rly	Brooks Instrument	Totalizer avail. Also for metering gases
Flow	Magnetic flowmeters	M	To 100K Gpm	Emf	A, press, tm	Fischer and Portei	Rcdr output also
Flow	Turbine flowmeters	M	To 36K Gpm	Turbine	Vac, A, rcdr	Fischer and Porter	Totalizer available
Flow	Flumes and weirs	M	To 90 mgd	Primary	Press, A, rcdr	Fischer and Porter	Uses Fischer and Porter float actuated transmitters
Flow	All-metal meters	M	To 320 gpm	Rotameter	A, press, rly	Fischer and Porter	Rcdr output also. Also for metering gases
Flow	Orifices, nozzles, venturis	M	To 20K gpm	Primary	A, press, rcdr	Fischer and Porter	Uses DP transmitters
Flow	Swirlmeter	M	–30K scfm	Vortex	Vac A, rcdr	Fischer and Porter	Gas flow only. Totalizor available
Flow	Turbine flow transmitters	M	.2-30K gpm	Turbine	Vac	Foxboro	Brochure not received
Flow	Primary device flow mtrs	M		Primary	Press, A, rly, tm	Foxboro	Press and float types. Brochure not received
Flow	Magnetic flow transmitter	M		Emf	A, rcdr, rly, tm	Foxboro	
Flow	Propeller type meters	M	To 60K gpm	Turbine	Vac, tm, rly	Hersey-Sparling	Rcdr output. Total flow output also
Flow	Stevens flow metrs (4 mdls)	M	To 50K gpm	Primary	Rcdr, dig, im	Leopold and Stevens	For weirs, flumes. Uses float or bblr. Total flow
Flow	Mark V flow meter	M	1.5-2K gpm	Fluid Drag	V, rcdr	Ramapo	Uses strain gage. Higher pipe flows available
Flow	Varea-meter			Rotameter		Wallace and Tiernan	Brochure not received. Also for metering gases
Flow	Le flowmeter	M	Unlimited	Ultrasonic		Westinghouse	Single range per instrument. Pipe and open channels
LEVEL MEASURING INSTRUMENTS							
Level	Model LM10A			Sonic		West Marine Elec	
Level	Float-operated transducer	1	3.5-30 ft	Float	R,V,A, rly, tm	Autocon	Rcdr output
Level	Press-operated transducer	1	231 ft adj	Press	V, A, rly, tm	Autocon	Rcdr output, adjustable range
Level	ML-MN transmitter	1	32 inches	Float	V	Badger Meter Mfg	Use with primary devices—flumes, weirs, open nozzles
Level	Series 200 liquilite	1	Fixed lvl	Electronic	Rly, tm	Controlotron	
Level	Sonargage (3 mdls)	3	.5-150 ft	Sonar	A, bcd, rly, rcdr	C. W. Stevens	Models 3000, 3100, 3200
Level	Super-sensor	2	Fixed lvls		Rly	Farris Chemical	High and low level control applications
Level	Float-actuated trmtrs	M	0-37 ft	Float	Press, A, rcdr	Fischer and Porter	Used with Fischer and Porter flumes and weirs, also
Level	Dp transmitters	M	0-2K inch	Press	A, nress, rcdr	Fischer and Porter	Range suppression provided
Level	Liquid level instruments			Float, bblr		Foxboro	Brochure not received
Level	Uni-sonic mdls 100, 200	1	0-200 ft	Sonic		Inventron	Also for sludge lvl
Level	Stevens liquid lvl instr	M		Float, bblr	Rcdr, dig, tm	Leopold and Stevens	4 models avail (3 with floats, 1 with bblr)
Level	Level controls	1	Fixed lvl	Float	Rly	Liq Lvl Lectronics	
Level	Metritape level sensor	M	2-500 ft	R tape	V,A,R, rly, dig	Metritape	Rcdr output. Upper limit based on tape length
Level	Interface/solids lvl ctrl	1	Fixed lvl	Lite refl	Rly	Met-Pro Water Treatmt	Mon and ctrl liquid or solid particles level
Level	Liquid level controller	2	Fixed lvls	Liq cnd	Rly	Photronic	High and low level control applications
Level	L5127-1C Liqui lvl det	1	Fixed lvl	Thermal R	Rly	Trans-sonics	
Level	P5200 series lvl indic	1	2-150 ft	Press	V, rly	Trans-sonics	V output assumed (To meter)
Level	Zyrotron liq lvl ctrl sys	2	Fixed lvls	Resistance	Rly	Zyrotron Industries	High and low level control applications
Sldg lvl	Mdl 8100 sldg lvl ctrl	1	Fixed lvl	Photoel	Rly	Keene	
PARTICLE SIZE MEASURING INSTRUMENTS							
Part size	Mdl 2150 cont part mon	2	2-100 mic	Lite scatr	Rcdr, rly	Particle Technology	Digital printer available

TABLE 5

AUTOMATIC MONITORING INSTRUMENTATION FOR WASTEWATER TREATMENT PROCESSES (2 of 2)

Variable	Instrument	Range	Range Limits	Method	Outputs	Manufacturer	Comments, other outputs, water quality variables
			WATER QUALITY MEASURING INSTRUMENTS (MULTI-VARIABLE INSTRUMENTS)				
H20 qual	Mdls 1200,1250,1400,1500	M		Color,othr	V,A,.dig, rly, tm	AES	Basic, NH_3, BR, CA, CR, CU, F, HD, HY, I, FE, NO, PO_4, SO, &
H20 qual	Mdl 9500 Water Qual Mon	M			A, rcdr, tm	Beckman	Basic &
H20 qual	Series 8000 anlzrs/ctrlrs	M		Color,othr	V, dig, tm, rly	Delta Scientific	Basic, NH_3, BR, HD, CL, CM, CR, CU, CY, F, HY, FE, I, PO_4, flow, &
H20 qual	(Variable name) meas sys	M			A, rcdr, rly, tm	Foxboro	PH, CL, TB, ORP, CND
H20 qual	Series CR 2 & CR anlzrs	M		Color	V, rly, rcdr	Hach Chemical	F, SI, PO_4, CM, SO, HD, FE, CL, HY, CU, PE, PH, &. Mon & ctrl
H20 qual	H20 qual sys (4 mdls)	M			V, rly, rcdr, tm	Honeywell	Basic, &. Lvl and low velocity outputs also
H20 qual	Mdl 1-1000 Water qual mon	M			V, rcdr, tm	KDI Poly-Technic	Basic, CA, NO, F, DC, CU, PB, AG, SO, BR, CY, HD, I,PER, THI, &
H20 qual	Mdl 900					Robertshaw	Brochure not received
H20 qual	CSM 6 Monitor	M	0-100 PPM	Color	V, rly, dig, tm	Technicon	NH_3, NO, PO_4, PH, HD, PN, SI, CU, F, FE, CR, DC, &. Rcdr output
H20 qual	Series 1600 H20 qual mon	M			V, rcdr, dig, tm	Union Carbide	Basic (except SRI) &
			WATER QUALITY MEASURING INSTRUMENTS (SINGLE VARIABLE INSTRUMENTS)				
CL	Mdl 880 resid anlzr-ctrlr	6	0-20 PPM	Amper	V, rly, tm, press	BIF	
CL	CL resid anlzr and mon	5	0-10 PPM	Amper	A, rly, rcdr	Capital Controls	
CL						Fischer and Porter	Brochure not received
CL	Resid CL anlzr mdl A-792	5	0-20 PPM	Amper	A, V, rly, tm	Wallace and Tiernan	Rcdr output avail
CND	Electrolytic CND cell			Electrode		Leeds and Northrup	Brochure not received
CND	CND monitor MDL 560B	M	0-10K PPM	Electrode	V, rly	Myron L	5 CND cells avail depending on application
CND	Mdls 101-115 CND sensors	M		Electrode	V	Universal Interloc	Flow, immersion types, Mdl 700 MA trmtr-anlzr avail
DO	DO analyzer mdl 1101					Union Carbide	Brochure not received
DO	Dissolved oxygen anlzr	2	0-25 PPM			Wallace and Tiernan	Brochure not received
DO	Mdl 3000 DO analyzer	2	0-15 PPM	Polar	V, rcdr, rly	Weston and Stack	Uses mdl A-40 DO probe. For gas meas also
F	Mdl 900F Fluoride anlzr	3	.1-100 PPM	Electrode	V,A	Beckman	
F						Fischer and Porter	Brochure not received
ORP						Fischer and Porter	Brochure not received
ORP	Mdls 330-331 ORP sensors	M		Electrode	V	Universal Interloc	Flow, immersion types. Mdl 1021 trmtr-anlzr avail
ORP	Potential cell				V	Wallace and Tiernan	Brochure not received
02 Demand	Oxymand	1	0-100ML 02	Respir	V, rly, rcdr	R.M.A. Development	Automatic periodic sampling for monitoring and ctrl
PH	Mdls RC, IC, R4, 30	1	2-12 PH	Electrode	V, rly, rcdr, dig	Analytical Measuremts	
PH						Fischer and Porter	Brochure not received
PH	PH Electrode assembly			Electrode		Leeds and Northrup	Brochure not received
PH	Mdl 20 and cont rcdg mtr	1	0-14 PH	Electrode	V, rcdr	Limnetics	Range is adjustable
PH	Mdls 320-323 PH sensors	M		Electrode	V	Universal Interloc	Flow, immersion, in-line types. Trmtr-anlzr avail
Sludge Den	Mdl 400		0-1	Sonics		National Sonics Corp.	
Susp slds	Mdl 150 fluid anlzr	3	10-150K PPM	Back scatr	V, A, rly, rcdr	Gam Rad	For meas susp slds and control of turbidity
Susp slds	Mdl 8200 anlzr/ctrlr	1	500-5K PPM	Electronic	V, rcdr, rly	Keene	
Susp slds	W.P.R.L. Susp slds mon	3	0-5K MG/L	Photoel	A, rcdr, rly	Partech	
TB	CR Turbidimeters (4 mdls)	M	0-10K JTU	Nephel	V, rly, rcdr	Hach Chemical	Models 1031, 1720, 1861, 1889
TB	Turbidiphot	1	10 PPM Adj	Photoel	Rly, rcdr	Photronic	
TC	Mdl 1610 TC analyzer					AES	Brochure not received. Mdl 1620 measures TOC and TC
TC	TC analyzer Mdl 1212					Union Carbide	Brochure not received
TEMP				Liq tube		Fischer and Porter	Brochure not received
TEMP	Thermocouple and thermohm			Thrmoc, R		Leeds and Northrup	Brochure not received
TEMP	Temperature probe	1	0-50 C	Thermister	V,	Limnetics	Range is adjustable
TOC	Mdl 1600 TOC analyzer	2	0-4K MG/L	Infrared	V, A, dig rly, tm	AES	Mdl 1620 measures TOC and TC
TOD	Mdl 225 TOD analyzer	1	0-200 PPM	Combustion	V, rcdr	Ionics	

Notes:
(1) Symbols and abbreviations are given in Table 6
(2) Refer to Table 8 for addresses of manufacturers

TABLE 6
SYMBOLS AND ABBREVIATIONS

A	CURRENT (AMPERAGE)
ADJ	ADJUSTABLE(RANGE OR SPREAD IS ADJ)
AG	SILVER
AMPER	AMPEROMETRIC
ANLZR(S)	ANALYZER(S)
AVAIL	AVAILABLE
BASIC	BASIC WATER QUALITY VARIABLES (TOTAL OF 8)
BBLR	BUBBLER
BCD	BINARY CODED DECIMAL
BOD	BIOCHEMICAL OXYGEN DEMAND
BR	BROMIDE
C	CENTIGRADE
CA	CALCIUM
CD	CADMIUM
CL	CHLORINE
CM	CHROMATE
CND	CONDUCTIVITY (BASIC VARIABLE)
COD	CHEMICAL OXYGEN DEMAND
COLOR	COLORIMETRIC
CONT	CONTINUOUS
CR	CHROMIUM
CTRL	CONTROL
CTRLR(S)	CONTROLLER(S)
CU	COPPER
CY	CYANIDE
DC	DISOLVED CHLORIDES (BASIC VARIABLE)
DET	DETECTOR
DIG	DIGITAL
DO	DISOLVED OXYGEN (BASIC VARIABLE)
EMF	ELECTROMOTIVE FORCE
FE	IRON
F	FLUORIDE
FT	FEET
GPM	GALLONS PER MINUTE
HD	HARDNESS
HY	HYDRAZINE
H2O	WATER
I	IODIDE
INDIC	INDICATOR
JTU	JACKSON TURBIDITY UNITS
K	1000 (FOR EXAMPLE, 4K = 4000)
LIQ	LIQUID
LITE	LIGHT
LVL(S)	LEVEL(S)
M	MULTIPLE RANGES WITHIN MIN/MAX LIMITS PRODUCED BY SINGLE/MULTIPLE MODEL
MAG	MAGNETIC
MDL(S)	MODEL(S)
MEAS	MEASURING
MGD	MILLION GALLONS PER DAY
MG/L	MILLIGRAMS/LITER
MIC	MICRONS
ML	MILLILITERS
MON	MONITOR, MONITORING
MTR(S)	METER(S)
NEPHEL	NEPHELOMETRIC
NH_3	AMMONIA
NO	NITRATE, NITRITE
ORP	OXIDATION REDUCTION POTENTIAL (BASIC VARIABLE)
OTHR	OTHER
O2	OXYGEN
PART	PARTICLE
PB	LEAD
PF	PERMANGANATE
PER	PERCHLORATE
PH	PH (BASIC VARIABLE)
PHOTOEL	PHOTOELECTRIC
PNL	PHENOLS
PO_4	PHOSPHATE
POLAR	POLAROGRAPHIC
PPM	PARTS PER MILLION
PRESS	PRESSURE
PRIMARY	PRIMARY FLOW MEASURING DEVICE(WEIR,VENTURI,ETC.)
QUAL	QUALITY
R	RESISTANCE
RCDG	RECORDING
RCDR	RECORDER
REFL	REFLECTION
RES	RESONANCE
RESID	RESIDUAL
RESPIR	RESPIROMETRIC
RLY	RELAY
SCATR	SCATTER
SCFM	STANDARD CUBIC FEET PER MINUTE
SI	SILICA
SLDG	SLUDGE
SLDS	SOLIDS
SO	SULFIDE, SULFATE
SRI	SOLAR RADIATION INTENSITY (BASIC VARIABLE)
SUSP	SUSPENDED
SYS	SYSTEM
TB	TURBIDITY (BASIC VARIABLE)
TC	TOTAL CARBON
TEMP	TEMPERATURE (BASIC VARIABLE)
THI	THIOCYANATE
THRMOC	THERMOCOUPLE
TM	TELEMETRY
TOC	TOTAL ORGANIC CARBON
TOD	TOTAL OXYGEN DEMAND
TREATMT	TREATMENT
TRMTR(S)	TRANSMITTER(S)
V	VOLTAGE
VAC	A-C VOLTAGE
VARIOUS	VARIOUS MODELS AVAILABLE
Σ	OTHER VARIABLES AVAILABLE

TABLE 7

MANUFACTURERS OF AUTOMATIC SAMPLERS

Brailsford & Company, Inc.
Milton Point
Rye, New York 10580

Instrument Specialties Company
4700 Superior
Lincoln, Nebraska 68504

Sirco Controls, Ltd.
8815 Silkirk Street
Vancouver 14, British Columbia

Sanitary Engineering Research Company
4205 31st Avenue South
Minneapolis, Minnesota 55455

N-Con Systems, Inc.
410 Boston Post Road
Larchmont, New York 10538

Chicago Pump
622 Diversey Parkway
Chicago, Illinois 60614

Infilco Compnay
P.O. Box 5033
Tucson, Arizona 85703

Megator Corporation
136 Gamma Drive
Pittsburg, Pennsylvania 15238

Penberthy
P.O. Box 112
Prophetstown, Illinois 61277

Sigma Motor, Inc.
3 North Main Street
Middleport, New York 14105

Testing Machines, Inc.
6078 Sherbrooke Street
W. Montreal 28, Quebec

Calhoun & Sons Instruments
8227 Hampton
Gross Ile, Michigan 48138

Pro-Tech, Inc.
Lester Industrial Center
Lester, Pennsylvania 19113

TABLE 8
MANUFACTURERS ADDRESSES

AES Automated Environmental Systems
135 Crossways Park Drive
Woodbury, New York 11797

American Meter Controls, Inc.
13500 Philmont Avenue
Philadelphia, Pennsylvania 19116

Analytical Measurements, Inc.
31 Willow Street
Chatham, New Jersey 07928

Autocon Industries, Inc.
995 University Avenue
St. Paul, Minnesota 55104

Badger Meter Manufacturing Co.
4545 West Brown Deer Road
Milwaukee, Wisconsin 53223

Beckman Instruments, Inc.
2500 Harbor Boulevard
Fullerton, California 92634

BIF
345 Harris Avenue
Providence, Rhode Island 02901

Brooks Instrument Div.
Emerson Electric Company
Hatfield, Pennsylvania 19440

Capital Controls Co., Inc.
Advance Lane
Colmar, Pennsylvania 18925

Controlotron Corporation
35 Central Avenue
Farmingdale, L. I. New York 11735

C. W. Stevens, Inc.
P.O. Box 619
Kennett Square, Pennsylvania 19348

Delta Scientific Corporation
120 East Hoffman Avenue
Lindenhurst, New York 11757

Farris Chemical Compnay, Inc.
P.O. Box 10126
Knoxville, Tennessee 37919

Fischer and Porter Company
Warminster, Pennsylvania

Foxboro Company
Neponset Avenue
Foxboro, Massachusetts 02035

Gam Rad, Inc.
16825 Wyoming Avenue
Detroit, Michigan 48221

Hach Chemical Company
Box 907
Ames, Iowa 50010

Hersey-Sparling Meter Company
4097 North Temple City Boulevard
El Monte, California 91730

Honeywell Industrial Div.
1100 Virginia Drive
Fort Washington, Pennsylvania 19034

Inventron Industries, Inc.
6508 South Arizona Avenue
Los Angeles, California 90045

Ionics, Inc.
65 Grove Street
Watertown, Massachusetts 02172

KDI Poly-Technic, Inc.
10540 Chester Road
Cincinnati, Ohio 45215

Keene Corporation
Water Pollution Control Div.
1740 Molitor Road
Aurora, Illinois 60507

Leeds and Northrup Company
Sumneytown Pike
North Wales, Pennsylvania 19454

Leopold and Stevens, Inc.
P.O. Box 25347
Portland, Oregon 97225

Limnetics, Inc.
6132 West Fond Du Lac Avenue
Milwaukee, Wisconsin 53218

Liquid Level Lectronics, Inc.
P.O. Box 1002
Richardson, Texas 75080

Met-Pro Water Treatment Corporation
5th Street and Mitchell Avenue
Lansdale, Pennsylvania 19446

Metritape Controls, Inc.
50 Commonwealth Avenue
West Concord, Massachusetts 01781

Myron L. Company
656 First Street
Encinitas, California 92024

National Sonics Corporation
43 Milbar Boulevard
Farmingdale, New York 11735

Partech, Ltd.
7 Broadwater Road, Welwyn Garden City
Hertfordshire, Great Britain

Particle Technology, Inc.
734 North Pastoria Avenue
Sunnyvale, California 94086

Photronic, Inc.
411 Cheltena Avenue
Jenkintown, Pennsylvania 19046

Ramapo Instrument Company, Inc.
Bloomingdale, New Jersey 07403

R.M.A. Development, Inc., Products Division
P.O. Box 1222
Fond Du Lac, Wisconsin 54935

Robertshaw Controls
P.O. Box 400
Knoxville, Tennessee 37901

Technicon Corporation
Tarrytown, New York 10591

Trans-Sonics, Inc.
P.O. Box 326
Lexington, Massachusetts 02173

Union Carbide Corporation
Instrument Department
5 New Street
White Plains, New York 10601

Universal Interloc, Inc.
17401 Armstrong Avenue
Santa Ana, California 92705

Wallace and Tiernan Div.
25 Main Street
Belleville, New Jersey 07109

Western Marine Electronics
509 Fairview Avenue North
Seattle, Washington 98109

Westinghouse Electric Corporation
P.O. Box 1488
Annapolis, Maryland 21401

Weston and Stack, Inc.
1426 Lewis Lane
West Chester, Pennsylvania 19380

Zyrotron Industries, Inc.
600 Huyler Street
South Hackensack, New Jersey 07606

1 *Accession Number*

W

2 *Subject Field & Group*

05D

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

5 *Organization*

The American Public Works Association, Chicago, Illinois 60637

6 *Title*

FEASIBILITY OF COMPUTER CONTROL OF WASTEWATER TREATMENT

10 *Author(s)*

American Public Works Association

16 *Project Designation*

EPA Contract 14-12-580; APWA 66-68

21 *Note*

22 *Citation*

23 *Descriptors (Starred First)*

*Computers, *Wastewater Treatment, *Monitoring, *Control

25 *Identifiers (Starred First)*

27 *Abstract*

ABSTRACT: This report contains the results of an investigation into the use of digital computers for management and control of wastewater treatment facilities. The objectives of the study included the generation of guidelines for implementation of digital computers for these purposes and recommendations for further relevant research.

For the purpose of gathering information, visits were made to plants and the literature was searched. A survey was conducted of current practices and problems in the operation of wastewater treatment plants. Emphasis was placed on the processes of secondary treatment with regard to management and control of unit processes, continuous monitoring needs, the influences of regulatory agencies, and certain local conditions. A set of guidelines and steps for computer control implementation and peripheral applications were evolved.

It was concluded that both off-line computer applications and on-line computer control in wastewater treatment are feasible and should be implemented.

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Abstractor R. H. Sullivan

Institution APWA Research Foundation

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